

# Research on Technology-Supported Older Adult Learning: A Systematic Review

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**Abstract:** With the rapid development of technology and continuing aging of the world population, lifelong learning of older adults using technology has attracted more attention in recent years. This study adopted a systematic review approach to explore research addressing the lifelong learning of older adults using technology from 2010 to 2021. This review aimed to analyze and reveal the characteristics and themes of contemporary research on technology-aided learning of older adults while also determining possible gaps in the existing body of literature. Key findings include an increased interest among educators, academic researchers, and social work practitioners in several countries/regions in promoting formal and experiential lifelong learning opportunities and the digital inclusion of older adults. With a clear understanding of reviewed research, this review concludes with evidence-based suggestions for future research into the lifelong learning of the global aging population. It informs the practice of lifelong learning by tapping into the power of technology with more precise and meaningful approaches.

**Keywords:** lifelong learning; older adults; technology; digital inclusion; systematic review

## Introduction

As technology pervades all aspects of modern society, people of all age groups must have equal opportunities to be included in digital activities and enjoy the same benefits brought by digital technologies. However, due to inadequate digital skills and other individual and structural barriers, many older adults cannot use digital technologies to their full potential as most young people do. Studies in recent decades have explored the social, cognitive, and health outcomes associated with older adults using Information and Communications Technology (ICT) in the form of emerging Internet, smartphone, or tablet technologies (Tyler et al., 2020). Technology can promote social connectivity through communication, lifelong learning and personal growth, and participation in daily activities, such as online banking,

shopping, entertainment, or e-health services (Ihm & Hsieh, 2015; Schreurs et al., 2017). A cluster analysis from the Pew Research Center shows that older adults have lower levels of “digital readiness” and personal learning activity, which is also associated with education level and socio-economic status (Horrigan, 2016).

The European Union has proposed that social and economic inclusion and quality of life for an aging population can be achieved through innovative solutions incorporating ICT (European Economic and Social Commission, 2010). Similarly, to bridge the digital divide, the Australian government has committed to investing \$50 million into imparting skills and knowledge to older adults to enable their participation in the modern digital economy (Commonwealth of Australia, 2015). Also, one of the goals of the United Nations in its 2030 Agenda for Sustainable Development (United Nations, 2021) is to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all to increase the proportion of youth and adults with ICT skills.

Lifelong learning, which resides in sociology in general and gerontology in particular and simultaneously intersects with many other disciplines, such as education, social work, and health care, aligns well with this United Nations (UN) goal. Educational technology as a field of research and practice plays a vital role in the lifelong learning of older adults and is a means to achieving this UN goal. Scholars from relevant fields have conducted theoretical and empirical research on the technology used to promote learning. For example, several studies exist on the technology used to combat social isolation (Baker et al., 2018) and technology acceptance in general among seniors (Peek et al., 2014), along with reviews on the use of assistive technology for seniors within healthcare settings (Ramprasad et al., 2019; Yusif et al., 2016). Despite researchers’ enthusiasm, current systematic literature reviews of research on the intersection of lifelong learning of older adults and technology are few.

To fill the research gap, we conducted a systematic literature review of original, peer-reviewed research studies on the learning of older adults or seniors with technology that used quantitative, qualitative, and mixed-methods approaches. This systematic review has the following objectives: (1) to gain a deeper understanding of characteristics and themes; (2) to identify challenges and gaps; and (3) to seek the future direction of research on the intersection of learning of older adults and technology. The review results will inform educators, social workers, and policymakers of the current state of technology-supported learning of older adults and possible future efforts of research and social services for improved aging and independent and active living.

## Theoretical Background

For effective communication with readers, several key terms must be clearly defined before presenting the theoretical background of this review.

- *Learning* is the effort an individual puts into a process “in which the person is always becoming, continuing to learn and develop, and the process is never complete during being, the whole of the life span” (Jarvis, 2004, p. 36). Learning, as a social phenomenon,

reflects the needs of individuals and their relationships and interactions among different social groups in the specific society to realize their full personal potential (Field, 2000).

- *Formal and Informal learning*: Formal learning occurs in a traditional, structured situation with pre-determined objectives and outcomes, planned instruction, and support. Examples of formal learning are found in schools and other educational programs. Informal learning, in contrast, occurs in a casual situation without any pre-determined learning objectives and outcomes, with a low degree of planning and more self-direction by the individual.
- *Lifelong learning* empowers individuals, supports independence, develops skills and competency, and contributes to sustained personal fulfillment and well-being (Glendenning & Battersby, 1990; Withnall, 2010). It comprises a conceptual framework to provide educational and social services and should be inclusive to individuals of different ages. A *lifelong learner* plans and monitors his learning, engages in self-evaluation and reflection, and receives feedback for change and improvement (Kirby et al., 2010).
- *Older adults* are defined by the United Nations (2017) as individuals aged 60 years or over. In this study, however, some samples of older adults in the articles reviewed were 50 years and older. The term *older adults* has often been used interchangeably with the term *seniors* in literature; yet, for this review, we will use the most frequently cited keyword in our set of articles, which is “older adults.”
- *Educational technology* is the study and ethical practice of facilitating learning and improving performance by creating, using, and managing appropriate technological processes and resources (Januszewski & Molenda, 2013). In this review, it refers to a broad approach to facilitate learning and enhance task performance of older adults using specific technology devices.

In addition to the essential concepts above, andragogy offers a theoretical understanding of adult learning. Knowles (1970) defined andragogy as “the art and science of helping adults learn” (p. 38). Henschke (2013) added “throughout life” to the end of this definition to indicate the importance of andragogy in lifelong learning. Knowles (1970) referred to adult learning as a set of assumptions regarding what it means to be an adult learner. Adults need to know why they should learn; learning should be self-directed; they should learn for transfer and application; adults have more significant life experiences affecting learning than youth do; adult readiness to learn is critical; and adults are motivated internally rather than externally (Henschke, 2013; Knowles, 1970).

Furthermore, the elements of andragogy incorporate experiential education, a method informed by the developmental theories of Piaget, the philosophies of Dewey, and the social constructivist theory of Vygotsky (Miettinen, 2000). Experiential education fosters the construction of individual meaning, honors prior experience, and values ideals central to social change. It meets the needs of older adult learners, who have the life experience necessary to make critical mental connections and the desire to apply educational content to an immediately relevant context (Furman & Sibthorp, 2013). Lifelong learning implies

learning across time, space, purpose, media, and formality (Walcutt & Malone, 2019).

Theories in aging studies have always attached more importance to opportunities for lifelong learning and the continuation of participation in old age to empower active aging and enhance the quality of life. For instance, Merriam and Kee (2014) described three frameworks linking aging, learning, and participation. These include successful aging, productive aging, and active aging. Successful aging includes three main components: reducing risk factors for disease and disability, maintaining high physical and cognitive functioning, and sustaining engagement in social and productive activities (Rowe & Kahn, 1997). Based on successful aging, the theory of productive aging further emphasizes the importance of productive engagement in old age. This theory contended that society should increase structural opportunities for older adults' participation in paid and unpaid work, including employment, volunteering, and caregiving. Active aging, another promising framework in gerontology, encourages older adults' participation in society and stresses the competence and knowledge that older adults possess (Daatland, 2005; Foster & Walker, 2015). Active aging research suggests that more socially engaged adults report greater satisfaction with themselves and their lives (Bjorklund, 2011). Some have considered this theory the start of North American movements and programs (e.g., senior centers, Lifelong Learning Institutes, and Universities of the Third Age) designed to engage older generations instead of keeping them passive or sedentary (Merriam & Kee, 2014). In today's information society, active aging is inseparable from "digital aging" with the continued efforts to conquer the "grey digital divide."

Inspired by Freire's (1972) philosophy of education, Glendenning and Battersby (1990) developed the concept of "critical geragogy," which allows older people to have greater control over their knowledge and thoughts. Accordingly, learning should empower older adults to challenge the oppressive and discriminatory conditions of old age. Critical geragogy emerged as a way to unsettle assumptions of older learners' dependence and to promote the idea that later-life learning can act as a vehicle for effecting social change (Formosa, 2012) by tapping into their rich life experience, knowledge, skills, and self-confidence (Withnall, 2010).

The term gerontechnology, coined by Graafmans and Brouwers (1989), blends the scientific study of aging (gerontology) with developing and distributing technological products, environments, and services. There is considerable interest in exploring technology's role in older adult learning, either in formal or informal learning environments. Technology literacy is usually gained in school or work settings; yet, with the rapid changes in knowledge and skills and the rise of social media and artificial intelligence, it is imperative that "learning to learn" skills are emphasized for older adults (Knapper, 2021).

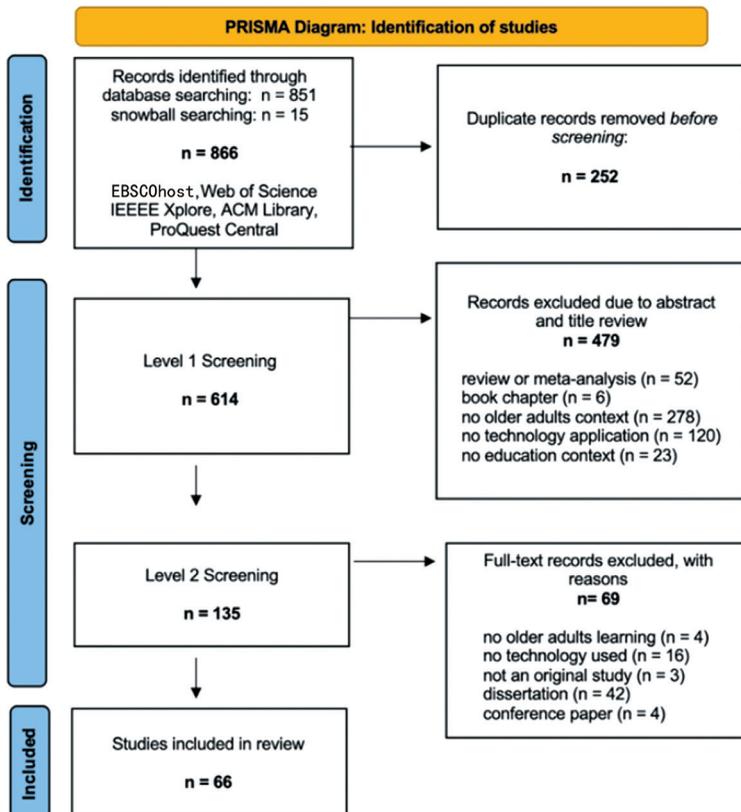
Formal learning with technology regularly takes place in groups wherein training is provided by ICT professionals in third age universities, cooperative learning extensions of higher education institutions, or adult education centers (Merriam & Bierema, 2014). Studies of the use and acceptance of ICT by older adults have reported variances based on education level, socio-economic status, and physiological conditions (Gonzalez et al., 2012; Macedo, 2017). Peek et al. (2014) proposed that other factors influencing the acceptance of ICT in

older adults include perceived usefulness, perceived easiness, safety and privacy concerns, costs, perceived need, social influence, and personal traits. As fewer formal education opportunities exist for digital skill development in later life, older adults may need to utilize informal learning opportunities. The increased access to informal learning is reshaping our conceptualization of learning away from scheduled courses or blocks of time toward an integrated, diverse lifelong learning continuum (Walcutt & Malone, 2019).

The theories described above, such as andragogy, active aging, and critical pedagogy, provide a valuable lens for examining the articles in this review. Furthermore, they help build a deep understanding of research on the intersection of learning of older adults and technology to seek implications for future directions for both research and improved social services.

## Methodology

This review was conducted according to widely used recommendations regarding undertaking systematic literature reviews (Moher et al., 2009). These recommendations outline the process for identification, screening, eligibility, and final inclusion in the systematic review (Figure 1).



**Figure 1:** The PRISMA Flow Diagram for the Systematic Review

## Research Questions

To achieve the three goals mentioned above and to provide a comprehensive picture of research (2010-2021) on technology-supported learning in older adults, three research questions guided this review:

1. What are the characteristics and themes of research on older adult learning using technology as reflected through peer-reviewed publications (2010-2021)?
2. What challenges and gaps in research on older adult learning using technology are reflected in peer-reviewed publications (2010-2021)?
3. What implications can be drawn from the review results for future research and practice?

A series of sub-questions was generated to guide and facilitate this systematic review:

- (RQ1) Which journals publish research on technology-supported learning in older adults?
- (RQ2) What are the countries/regions of authors researching technology-supported learning of older adults?
- (RQ3) What are the most frequently published research topics on technology-supported learning in older adults?
- (RQ4) In what ways have the topic trends of this research changed over time, as revealed by the keywords?
- (RQ5) What research methodologies are used in the research on technology-supported learning in older adults?
- (RQ6) What types of technology are used in research on technology-supported older learning in older adults?
- (RQ7) What is the demographic information of participants in research on technology-supported learning in older adults?
- (RQ8) What are the common limitations, challenges, and gaps in research on technology-supported learning in older adults?

## Search Strategies

We searched for articles published between 2010 and July, 2021 and those written in English. We focused on the following databases: EBSCOhost, Web of Science, IEEE Explore, ACM Library, and ProQuest Central. These databases cover a wide range of literature in education

and technology. We used different combinations of terms that generated eight search strings (Table 1). Further snowball searching generated more records totaling 866. All search results were logged into the reference-management software Zotero. After eliminating duplicates, we had 614 records to screen.

**Table 1.** Defined Keywords and Their Order in the Individual Search Queries

<i>1st keyword</i>	<i>AND</i>	<i>2nd keyword</i>	<i>AND</i>	<i>3rd keyword</i>	
learning		educational technology	OR	older adults	OR
lifelong learning		technology		senior people	
lifelong education					

For the Level 1 screening with abstract and title review, we used the following inclusion criteria for original and peer-reviewed articles: 1) The article was written in English. 2) The study sample included older adults/senior people. 3) The research investigated technology. Numerous articles were excluded because the term “seniors” generated seniors in high school or higher education. The term “older adults” often generated adult education programs or non-traditional college students rather than an older sample of participants.

In the Level 2 screening, we read 135 full articles and applied the inclusion criteria to narrow our studies to 66. The articles excluded in this screening did not present an original study (n=3), did not study older adult learning (n=4), or did not use technology as part of the design (n=16). Additionally, we decided to exclude the remaining conference papers (n=4) and dissertations (n=42) that provided valuable insight into the field yet were not comparable to peer-reviewed journal articles. They would not fit into the categories in our data extraction template. This process left in our final inclusion 66 studies by researchers in 28 countries/regions with sample populations primarily of adult learners aged 50 years and older.

### Data Extraction and Analysis

To retrieve relevant data from each article matching the inclusion criteria, a template guiding the extraction process was developed in Microsoft Excel. The template covered different aspects of the studies, including keywords, research questions and purpose of study, the sample, methodology and design, data analysis, theoretical framework, key findings, recommendations for practice, future research, limitations, and suggestions for future research. The terminology used in each original paper was preserved within the template to reduce researcher bias. The two researchers coded a few articles independently and then compared their results to ensure instrument reliability and process validity. In the case of qualitative studies and data from mixed methods studies, themes were also coded; for quantitative data, we entered the variables and data analysis tests used. Once the template was complete, we rechecked the coding for consistency and applied descriptive statistics

to answer specific research questions. Thematic analysis was used to review each article's results and discussion sections to synthesize common ideas and identify gaps and potential areas for further research. The open-source software program, VOSviewer, was used to represent co-occurrence links between keywords visually.

## Results

In this systematic review, we synthesized and summarized key findings from the selected articles on technology-supported lifelong learning of older adults. In this section, we first declare results to answer each sub-research question that reveals the characteristics and themes of research on technology-supported older adult learning, including the challenges and gaps reflected in peer-reviewed publications (2010-2021). Next, we present thematic analysis results with emergent themes from the selected research.

### Characteristics and Themes of the Selected Research

#### ***(RQ1) Which journals publish research on technology-supported learning of older adults?***

Our systematic review included studies published in 66 journals. Table 2 illustrates journals that were included more than once, the number of articles, the impact factor, the publisher, and the country/region of publication. Almost a quarter of the articles (14 out of 66; or 21.2%) were published in *Educational Gerontology*, followed by *Computers in Human Behavior* in the United Kingdom. Out of 66 journal articles, 30 (45.45%) were published by the seven journals, as shown in Table 2.

**Table 2.** Journals Included More than Once in the Review and Their Information

<i>Journals in Review</i>	<i>Number of Articles</i>	<i>Impact Factor</i>	<i>Publisher</i>	<i>Country/Region of Publication</i>
Educational Gerontology	14	0.490	Routledge	UK
Computers in Human Behavior	4	6.829	Elsevier	UK
Gerontology & Geriatrics Education	3	1.170	Routledge	US
International Journal of Lifelong Education	3	0.620	Routledge	UK
Computers & Education	2	8.538	Elsevier	UK
Journal of Extension	2	0.240	Extension Journal, Inc.	US
New Media & Society	2	8.061	Sage Publications	UK

**(RQ2) What are the countries/regions of authors researching technology-supported learning of older adults?** Most authors of the selected articles were from the United States (26), followed by Spain (6), China (5), and the United Kingdom (4), which reflects the authors' locations and, very likely, the locations where these studies were conducted. Four articles (Anikeeva et al., 2019; Blažun et al., 2012; Tsai et al., 2015; Tsai et al., 2019) were written through collaboration by authors in two different countries/regions. Table 3 lists the top five among the 28 countries/regions of the authors.

**Table 3.** Countries/Regions of Authors in the Review

<i>Countries/Regions of Authors</i>	<i>Number of Authors</i>
Australia	3
Canada	3
Mainland China	3
Finland	3
Spain	6
Taiwan, China	5
United Kingdom	4
United States	26

**(RQ3) What are the most frequently published research topics on technology-supported older adult learning?** We analyzed the 474 keywords from 52 of our 66 articles, which included keywords in determining the most frequently published topics. The journal *Educational Gerontology* does not include keywords in published articles. It must also be mentioned that ICT, the acronym for “information communication technology,” is commonly used to describe various digital technologies to access information, such as the Internet, wireless networks, mobile devices, and other modes of communication. Table 4 lists the top 10 keywords according to their frequency in the selected articles. The high frequency of these keywords reflects researchers' degree of interest in these topics.

**Table 4.** Frequency of Keywords from the Reviewed Studies

<i>Keyword</i>	<i>Frequency</i>
older adults	18
technology	15
learning	15
digital	12



Furthermore, we charted all keywords over time using a spreadsheet to capture their presence during the selected publication timeframe (2010-2021). Figure 3 reveals the top 10 most persistent research topics over time, including “ICT,” “lifelong learning,” “digital,” “inclusion/divide,” “training/education,” and “community.” The analysis also reveals that in recent years, topics such as “participation” and “access” (2018), “self-directed learning” (2019), and “distance learning” (2021) were explored. The increasing interest in “distance learning” (2021) in publications reflects a global learner transition toward remote and distance learning during the COVID-19 pandemic.

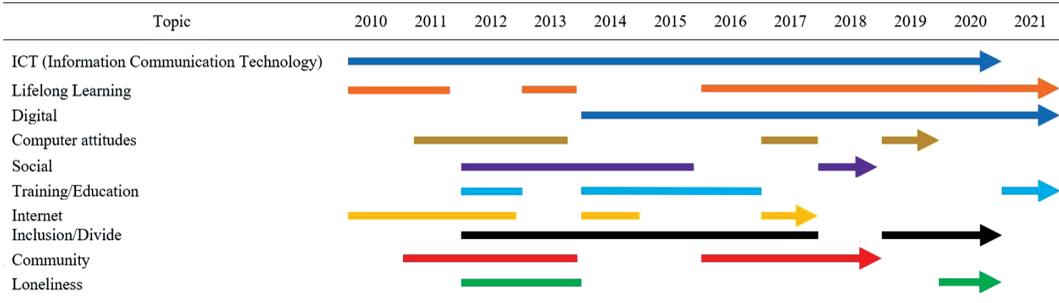


Figure 3: Topic Trends by Year (2010 -2021)

**(RQ5) What research methodologies are used in the research on technology-supported learning in older adults?** This systematic review includes 28 quantitative research studies, 21 qualitative studies, and 17 mixed-methods studies, as reported by the authors. Table 5 categorizes each study by design. In total, 17 research studies (25.8%) did not specify their research design, which we found to be unusual and an essential quality criterion for systematic reviews that others might use to exclude these studies. The most frequently employed designs were quantitative with descriptive statistical analysis (9 studies, or 14% of the total) and experimental ones (7 studies, or 11% of the total) with descriptive and inferential statistical data analysis methods.

Table 5. Research Methodologies Reported by Authors in the Reviewed Studies

Methodology	Number of studies	Frequency
Qualitative		
Case study	1	2%
Phenomenology	4	6%
Ethnography	2	3%
Grounded theory	2	3%
Action research	2	3%
Interviews	2	3%

Continued

<i>Methodology</i>	<i>Number of studies</i>	<i>Frequency</i>
Document analysis	1	2%
Unspecified	7	11%
Quantitative		
Program impact evaluation	1	2%
Experimental	7	11%
Exploratory	3	5%
Descriptive	9	14%
Unspecified	8	12%
Mixed Methods		
Action research	1	2%
Convergent	2	3%
Community-based participatory	1	2%
Case study	2	3%
Program evaluation	5	8%
Exploratory	2	3%
Exploratory sequential	1	2%
Hypothetical deductive	1	2%
Unspecified	2	3%

**(RQ6) What types of technology are used in research on technology-supported learning of older adults?** In many studies, older adults were enrolled in technology learning courses and were surveyed and observed as they learned new applications. Those applications, when specified, most frequently addressed the use of the Internet and navigation of various websites (10 of 66 studies, or 15.2%). Other researchers studied older adults’ use of computer software, such as word processing or spreadsheets, followed by tablets, e-learning, and assistive technology. Table 6 lists the applications cited in the selected studies. In many cases, the term “ICT” was used broadly without reference to the exact applications used by participants. Findings from these studies focused on methods to engage older learners, types of training materials they preferred, and ways ICT could affect their well-being.

**Table 6.** Technology Applications and Devices in Reviewed Studies

<i>Applications and Devices</i>	<i>Frequency</i>
The Internet/Web navigation	10
Word processing/Spreadsheets	4
Tablets	4
e-Learning	4
Assistive Technology	4
Video/Computer Games	4
Digital Storytelling	1
Concept Mapping	1
Webinars	1
Video on Demand	1
Second Life/Virtual World	1
Mobile Phones	1
VOIP Communication System	1
Online Personal Learning Networks	1

**(RQ7) What is the participants' demographic information in research on technology-supported learning of older adults?** The majority of these studies (54 out of 66; or 82%) collected and reported the age group of their study participants. The “older adults” in the selected studies refers to individuals aged at least 55 years or above, although six studies included participants aged 40 years and above. Four studies had sample groups aged “50 years and younger.” As shown in Table 7, there are gaps in research specific to individuals in the upper age ranges, such as 65 years and older. Additionally, 28 studies used sample populations with a majority of female participants. Barring one study that specifically sampled females in Taiwan, China (Lin et al., 2012), in most cases, the rest recruited more female participants without any explanation. Participants were most frequently recruited from ICT courses in senior centers, lifelong learning centers, universities of the third age, public libraries, and assisted living facilities.

**Table 7.** Demographic Information of Participants in Reviewed Studies

<i>Age group</i>	<i>Frequency</i>
50 years or younger	4
40 years or older	4

Continued

<i>Age group</i>	<i>Frequency</i>
45 years or older	2
50 years or older	6
55 years or older	20
60 years or older	9
65 years or older	7
70 years or older	2
<i>Gender</i>	
> 50% female	28
> 50% male	3

**(RQ8) What are the common limitations in research on technology-supported learning in older adults?** Frequently cited limitations in the selected studies (25 of 66, or 37.8%) were related to homogeneous participants with similar characteristics, such as age group or ethnicity, an imbalanced gender ratio, use of one or limited locations, and the self-identified nature of technology users to the exclusion of non-users. In 15 of 66 studies (22.7%), researchers specifically cited a small sample size and the use of convenience sampling as limitations. Other limitations (6 of 66, or 9%) included a short study timeframe, the translated text not accurately conveying the original questionnaires' intended meaning, or incomplete data sets. An unusual observation was that 20 of 66 studies (30.3%) did not include a limitations section or report any possible limitations. The typical limitations reflect the challenges of researching technology-supported learning in older adults. Table 8 summarizes different types of limitations reported in the reviewed studies.

**Table 8.** Limitations Reported in Reviewed Studies

<i>Limitation</i>	<i>Frequency</i>
Demographic	25
Sampling	19
Other	6
None Specified	20

The descriptive statistical reports above reveal the characteristics of research on technology-supported learning in older adults as reflected in peer-reviewed publications (2010-2021). The following section reports the themes discovered in our review.

## Thematic Analysis Results

***Promoting Digital Inclusion of Older Adults.*** The selected publications reveal certain researchers' passion for promoting the digital inclusion of older adults. For example, Gu et al. (2011) analyzed the usability of two lifelong learning websites for older adults in Shanghai to integrate them into a lifelong learning network. Through this study, usability problems were identified in the websites, which helped generate practical suggestions for improving the learning experience of older adult users. Pinzon-Pulido et al. (2019) studied how the "En buena edad" (at a good age) web platform in Spain focused on the World Health Organization's four pillars of active and healthy aging. They incorporated feedback from multiple stakeholders to improve the platform's functionality. They noted in their findings that older people were essential advocates of their health interests and concerns and that they need to be recognized with respect and given a voice when developing policies and plans (Pinzon-Pulido et al., 2019).

Another example is Reneland-Forsman (2018), who discussed digital exclusion as an obstacle for older adults in Sweden as the latter struggled to interact independently in social, cultural, political, and commercial contexts using digital interfaces. Reneland-Forsman (2018) equated their lack of digital use to a loss of independence and civic participation. Munoz et al. (2020) examined how older adults in Spain engage in online social activities as an impetus to the skills necessary for active learning, digital inclusion, and sustainable adult education. They suggested a sustainable adult education program for effective digital inclusion (Munoz et al., 2020). All these studies advocate for and promote the digital inclusion of older adults in social contexts.

***Formal and Informal Learning.*** The review revealed that most of the selected studies were implemented in formal learning situations, which differed from informal learning at home or during travel. Organizations that cater specifically to lifelong learning, such as the Road Scholar Lifelong Learning Institute Network and the UNESCO Institute for Lifelong Learning (UIL), take a holistic and integrated approach to lifelong learning as the guiding paradigm for 21st century education. They support lifelong learning and educational equity, focusing on literacy and non-formal primary education. Nygren et al. (2019) found that non-formal learning skills were positively associated with problem-solving skills in technology-rich environments, indicating that adults' learning ecologies are a combination of formal, non-formal, and informal learning. Walcutt and Malone (2019) contend that while we have primarily documented and valued only formal learning experiences, "informal and experiential learning can have as much, or even more, impact on individuals' abilities to acquire, assimilate, and apply knowledge" (p. 77).

***Barriers to ICT Usage Among Older Adults and Recommendations.*** Our review identified several critical barriers to older adults' ICT use and recommendations from selected studies. For instance, owing to age-related functional and cognitive declines, several older adults expressed fear, anxiety, discomfort, lack of confidence, or lack of general interest in learning, especially when ICT education programs or the use of new devices required massive

memorization and complicated steps (Heaggans, 2012; Hill et al., 2015; Morin et al., 2021). Another barrier was the financial cost of ICT. One study investigating older adults' ICT usage and its connection with social well-being (Ihm & Hsieh, 2015) found that elderly persons' socio-economic status was the strongest predictor affecting access to ICT.

Other individual factors also correlate to adverse effects on older adults' learning and usage of ICT. These include pre-retirement ICT use (Friemel, 2016), low digital technology skills (McGinty, 2020), lack of ICT awareness and motivational access (Chirlesan et al., 2016), and concerns about the security of personal data, especially when handling money through online platforms (Hill et al., 2015). Perhaps more importantly, the causes of older adults' digital divide stem from contextual factors, particularly the lack of appropriate educational resources, information, and opportunities to develop and practice ICT skills (Anikeeva et al., 2019). These contextual constraints further decrease older adults' confidence in and motivation for learning with technology at large.

In response to the COVID-19 pandemic, many selected studies have made practical recommendations to design and promote effective learning in older adults while considering their characteristics, needs, and constraints. Researchers have suggested prolonged learning periods, sufficient practice time, scaffolded tasks, attention to ergonomic issues, and simply written printed training materials and visual aids when assisting older adults' learning with technology (Calvo et al., 2017; Huber et al., 2014; Wood et al., 2010; Zheng et al., 2016). Many have also advocated for more learner-centered approaches and increased time to collaborate with peers (Lin et al., 2012; Prodromou et al., 2019; Sayago et al., 2013). While peer mentoring was considered highly beneficial for teaching content, an intergenerational approach was recommended (Sanders et al., 2013; Stanley et al., 2019). As summarized by Chen and Chan (2014), gerontechnology interface designers need to make allowances for their aging audience's physical, cognitive, and emotional needs.

## Review Summary

The research on technology-supported older adult learning (2010-2021) primarily orients around topics of "ICT," "lifelong learning," and "digital inclusion/divide" for active aging of older adults. For research methods, 28 out of 66 studies used quantitative research methods, followed by 21 studies that used qualitative research methods, and 17 that used mixed methods research. The most frequently studied technology applications included the Internet/web navigation, word-processing/spreadsheets, tablets, assistive technology, and video/computer games. Most of the participants in these studies were 55-year-old adults, primarily women. Among the 66 studies from 28 countries/regions, 26 were from the United States. The common challenges and gaps reported included difficulty recruiting study participants with well-balanced demographic characteristics to have a sample size large enough to reflect the intended population, study time that was often too short to produce valid and reliable research results, and difficulty retaining participants throughout the study. Researchers should be prepared to address these issues in future studies.

Furthermore, our review demonstrates the research themes at the intersection of learning in

older adults and technology. Many selected articles focused on ways to gain positive attitudes toward technology (technology acceptance) and to sharpen technical skills through formal learning pathways for older adults. The variables most frequently explored were loneliness, social connectivity, and ICT anxiety. Our review shows that developing and implementing effective and efficient solutions to meet older adults' learning needs for digital inclusion vary widely by country and locale. The second theme was that most studies on technology-supported learning in older adults were conducted in formal learning situations. However, researchers also recognized that older adults learn through informal learning environments.

Additionally, the selected studies identified common barriers in technology-supported older adult learning, especially ICT. They made practical recommendations, such as adopting the learner-centered approach, recognizing the unique needs of older adults, and taking an intergenerational approach. It would be noteworthy to incorporate these measures in future practice and research.

The statistical and thematic analysis of the reviewed articles suggests answers to research questions on characteristics, themes, and research gaps in technology-supported older adult learning revealed through publications (2010-2021). Further evaluation of results provided ideas for the following discussion, with evidence-based recommendations for future research and practice.

## Discussion

We found that a limited variety of technologies was studied among the selected articles. Only two studies (Hermann et al., 2012; Parker et al., 2011) addressed the use of assistive technology to empower older adults, in both cases, to shop for groceries and prepare food independently. We believe the learning needs of older adults are diverse, and research that helps them with their learning needs should include more technologies, such as wearable technology, learning with home robots, and other assistive technology tools. As Pihlainen et al. (2021) pointed out, digital literacy is a narrow definition that covers a range of technology skills; however, socio-emotional aspects of technology use are even more important for older adults. These ideas relate to critical geragogy, promoting older learners' independence and the use of lifelong learning to effect social change (Formosa, 2012), which are also essential to digital inclusion. The technical, socio-emotional, and cognitive aspects of older adults learning with technology should be considered if active aging is the ultimate driving force behind these learning efforts.

One finding was that most selected studies were conducted in formal learning environments with established learning objectives and outcomes. Technology-supported older adult learning occurs in both formal and informal situations. LIFE Center (2005) indicated that more than 80% of learning during our life span occurs in informal learning environments. Our review indicates that more research is needed to explore informal technology-supported older adult learning.

With the rapid development of smartphones, learning how to use them in the best way

possible should not be limited to communication and social connectivity. Older adults must be digitally included as more services transition to a digital format. Research is needed to explore practical ways to assist older adults in using smartphones for daily activities and routine services, such as managing social benefits, e-health platforms, food delivery, and transportation. Smartphones offer a way to be digitally included and are a conduit to informal learning opportunities. More research on older adult learning with smartphones and other digital devices is needed to align with research on current social efforts to promote active aging through lifelong and life-wide learning (LIFE Center, 2005).

Additionally, we want to draw readers' attention to the demographic information of study participants, skewed in terms of gender and age representation among the selected studies. There were 703 million persons aged 65 years or over in the world in 2019; this figure is projected to double to 1.5 billion in 2050 (United Nations, 2019). In China, the population over age 60 reached 264.02 million, 18.4% of the nation's population, according to China's seventh population census (Chen, 2021). As such, more research is needed on this upper age group. Additionally, a gender balance must be maintained if researchers want to theorize learning with this group of people and provide evidence-informed guidance to improve active aging through lifelong and life-wide learning.

Accordingly, we offer the following suggestions:

- In accordance with numerous researchers (Demirbilek, 2010; Ihm & Hsieh, 2015; Kuo et al. 2013; Munoz-Rodriguez et al., 2020; Seifert et al., 2017; Winstead et al., 2013), we recommend longitudinal studies for future research on active aging through learning to measure changes in confidence, competence, and participation accurately.
- Future studies should pay more attention to clarity in methodology to increase study validity and assist other researchers in replicating these studies at their sites. Additionally, researchers must address the imbalance in gender ratio among participants (existing studies have significantly fewer male subjects) to fully explore gender as a variable.
- Future research should expand digital access with devices that individuals already own and could use for greater functionality, such as smartphones or smartwatches, home robots, and other assistive technology. Specifically, we hope to see future studies explore older adult learning with various technologies in informal situations. The results of such research can help promote lifelong and life-wide learning with evidence-based principles.
- We suggest that researchers and practitioners in social service, gerontology, and educational technology collaborate more in field-needed and field-based research. Such collaborations can tap into modern technologies that support education in health, independence, safety, and social engagement, which are critical aspects of active aging through learning.
- For educators who design and implement personalized training opportunities for older adults, we recommend they consider the principles of adult learning and the unique needs

and special characteristics of this age group. These needs include sensitivity to ergonomic issues and leveraging the benefits of peer learning. We recommend that they draw on their life experience, knowledge, and skills for learning.

## Conclusion

After applying our selection criteria discussed in the research methods section above, we significantly narrowed the available studies to capture the research on technology-supported learning in older adults. Despite our use of a thorough search strategy, some empirical studies may not have been identified (e.g., gray literature such as unpublished documents and reports); we only included reviews that were published in peer-reviewed journals. As we coded our articles and charted them based on categories for quality assessment, we realized that the lack of thorough study reporting in many instances and the heterogeneity of technology applications and research questions prevented us from conducting a meta-analysis. Another limitation is that only articles written in English were included in our review due to our practical inability to survey all studies in all languages. However, we could incorporate the results of studies from many different national contexts instead of focusing solely on studies dealing with English-speaking countries/regions. Our findings can appropriately guide other scholars interested in the intersection of lifelong learning for older adults and technology. We aspire to promote field-needed and field-based research as well as research-informed and evidence-based practice pertaining to technology-supported learning in older adults.

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