REVIEW ARTICLE

Thematic Review of Design Factors and Application Perspectives to Enhance Satisfaction of Smart Indoor Gardens Among the Elderly

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Abstract

Smart indoor gardens (SIGs) represent an emerging innovation in urban agriculture with substantial potential to improve the quality of life for older adults. This thematic review synthesises design factors and application perspectives from twenty-five selected studies to identify strategies that enhance elderly users' satisfaction with SIGs. The analysis yielded five overarching themes: (1) user-centred design and accessibility, (2) multisensory and emotional well-being, (3) technological integration and automation, (4) interaction and community engagement, and (5) sustainability and environmental impact. The findings highlight the critical role of inclusive design, seamless automation, socially oriented approaches, and sustainable practices in developing age-friendly SIG environments. Hydroponic-based indoor gardening offers opportunities to introduce fresh vegetables, herbs, and other plants into living spaces, creating aesthetically pleasing environments while promoting both physical and mental well-being. This is especially valuable for older adults with limited access to outdoor spaces. By integrating innovative design principles across multiple domains, SIGs can serve as a holistic solution to enhance user satisfaction and support healthy, independent ageing.

Keywords: *Aging, smart indoor gardens (SIGs), design factors, the satisfaction of the elderly, thematic review*

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Introduction

Integrating smart technologies with gardening and horticulture has become an essential area of research, particularly in enhancing the experience and emotional well-being of older people. Smart gardening systems utilize Internet of Things (IoT) technology and are designed to facilitate the maintenance of gardens whilst catering for the specific needs of older people. These systems not only automate tasks such as watering and monitoring plant health but also aim to create an emotionally satisfying environment that resonates with the memories and preferences of older users (Chakraborty et al., 2022). Research has shown that smart homes and gardens can significantly improve the quality of life of older people by promoting independence and increasing emotional fulfilment. For example, smart home technologies have been shown to support older people's physical and mental health by enabling them to engage in gardening activities and foster an emotional connection with nature (Zhang et al., 2020). The design of these smart systems often incorporates features that cater to older adults' emotional needs, such as familiar aesthetics and user-friendly interfaces that evoke positive feelings and memories associated with gardening (Heród et al., 2024).

Furthermore, the emotional design of smart gardening technologies is crucial for the acceptance of older people. Research has shown that designing gardens with older adults' emotional and psychological needs in mind can increase engagement and satisfaction (Soga et al., 2017). For example, therapeutic gardens that evoke feelings of nostalgia and familiarity can significantly enhance the emotional experience of older users, providing them with a sense of belonging and comfort (Heród et al., 2024). Incorporating elements such as easily accessible plants and comfortable seating areas further supports older adults' emotional and physical well-being (Yaacob et al., 2022). In addition, using smart technologies in gardening not only meets practical needs but also enhances social interaction and community engagement among older adults. Smart gardening systems can facilitate shared gardening experiences that benefit social and emotional well-being (Maddali & Lazar, 2020). By facilitating collaborative gardening activities, the integration of smart systems that prioritise emotional design and user-friendly features can help alleviate the loneliness commonly experienced by older adults, thereby improving their overall emotional well-being (Cosco et al., 2019). In conclusion, integrating smart gardening technologies with the emotional needs of older adults has the potential to create gardening experiences for older adults that are practical and deeply satisfying.

However, the increasing prevalence of smart indoor gardens presents an opportunity to enhance the quality of life for the elderly. However, significant research gaps remain in understanding how design factors influence user satisfaction. Current literature highlights the importance of ergonomics, usability, and emotional design in creating user-friendly interfaces for seniors (Miraz et al., 2021). Additionally, the role of social interaction facilitated by smart gardens in combating loneliness and enhancing mental health among older adults remains under-explored (Vassanyi et al., 2024). Addressing these gaps is essential for developing effective smart gardening solutions tailored to the aging population.

Therefore, the objective of this thematic review is to analyse the issues discussed in publications from 2014-2024 through the following research question: What are the design factors and application perspectives to enhance satisfaction in smart indoor gardens for the elderly?

Methodology

The methodology of this study followed the Thematic Review (TR) proposed by Clarke and Braun (2013) and using ATLAS.ti as a tool to apply the thematic analysis procedure while conducting the literature review. A thematic review was chosen to integrate of findings from diverse disciplines—such as gerontology, human–computer interaction, and sustainable design—by focusing on patterns and conceptual relationships rather than quantitative aggregation. This method is particularly suited for exploratory studies aiming to develop conceptual frameworks and generate design implications. Clarke and Braun (2013) defined thematic analysis as identifying patterns and constructing themes through in-depth reading of the subject matter. The following step is to identify the pattern and construct a category to understand the trend of smart indoor garden (SIG) publications around the world. The tenets of the research are to analyse and interpret the findings to recommend future research in SIG subjects. The selection of literature was performed according to several selection criteria: 1) publication from 2014-2024 around the world, 2) from SCOPUS, WoS, and ProQuest database, as shown in Table 1, 3) include at least smart gardens or home gardens or green spaces ; 4) focus on garden design in the city, especially indoor garden design for older user groups. The physical health, cognitive profiles, and potential special needs of the elderly participants were not explicitly reported in the study.

Table 1: Search Strings from Scopus, WoS and ProQuest

SCOPUS	(TITLE-ABS-KEY (“smart garden*” OR “intelligent garden*” OR “intelligent indoor garden*” OR “smart indoor garden*” OR “ smart indoor garden*” OR “automated garden*” OR “smart horticulture” OR “smart plant*”OR Biophili*) AND (elderly OR seniors OR “older adults” OR “aging population” OR “senior citizens” OR “aging individuals” OR “elderly users” OR “old people” OR ageing OR “elderly people” OR “old adults”) AND(“design considerations” OR “design factors” OR “design features” OR “design elements” OR “user-centred design” OR “design principles” OR “interface design” OR “interaction design” OR “interaction features” OR ergonomics OR aesthetics OR “user experience” OR usability OR “product design” OR “user interaction” OR “innovative design” OR “smart technology” OR IoT OR sensor*)) AND (well-being OR “mental health” OR “quality of life” OR “emotional health” OR “emotional well-being” OR “mental wellness” OR “satisf*”)) AND (LIMIT-TO (LANGUAGE, “English”)) AND (LIMIT-TO (PUBSTAGE, “final”))	11 results
WoS	(TS=(“smart garden*” OR “intelligent garden*” OR “intelligent indoor garden*” OR “smart indoor garden*” OR “smart indoor garden*” OR “automated garden*” OR “smart horticulture” OR “smart plant*” OR Biophili*) AND (elderly OR seniors OR “older adults” OR “aging population” OR “senior citizens” OR “aging individuals” OR “elderly users” OR “old people” OR ageing OR “elderly people” OR “old adults”) AND (“design considerations” OR “design factors” OR “design features” OR “design elements” OR “user-centred design” OR “design principles” OR “interface design” OR “interaction design” OR “interaction features” OR ergonomics OR aesthetics OR “user experience” OR usability OR “product design” OR “user interaction” OR “innovative design” OR “smart technology” OR IoT OR sensor*) AND (well-being OR “mental health” OR “quality of life” OR “emotional health” OR “emotional well-being” OR “mental wellness” OR “satisf*”)) AND (LA=(“English”)) AND (PUBSTAGE=(“final”))	7 results
Proquest	(TI,AB,KW(“smart garden*” OR “intelligent garden*” OR “intelligent indoor garden*” OR “smart indoor garden*” OR “smart indoor garden*” OR “automated garden*” OR “smart horticulture” OR “smart plant*” OR Biophili*)AND (elderly OR seniors OR “older adults” OR “aging population” OR “senior citizens” OR “aging individuals” OR “elderly users” OR “old people” OR ageing OR “elderly people” OR “old adults”) AND (“design considerations” OR “design factors” OR “design features” OR “design elements” OR “user-centred design” OR “design principles” OR “interface design” OR “interaction design” OR “interaction features” OR ergonomics OR aesthetics OR “user experience” OR usability OR “product design” OR “user interaction” OR “innovative design” OR “smart technology” OR IoT OR sensor*)AND (well-being OR “mental health” OR “quality of life” OR “emotional health” OR “emotional well-being” OR “mental wellness” OR satisf*))AND (la.exact(“English”)) AND (pub(EXACT(“final”)))	22 results

The process of writing a Thematic Review paper (TR) proposed by Zairul et al. (Zairul, 2021) (Zairul & Zaremohzzabieh, 2023) using ATLAS.ti as a tool to apply the thematic analysis procedure. The rigour of this step ensures the credibility of this document by applying the following steps (Figure 1): In Stage 1 (Formulating RQ), a research question was developed that was neither overly broad nor excessively narrow to ensure focus and relevance. Stage 2 (Articles screening) involved searching at least two academic databases—Scopus, Web of Science, and ProQuest—using Boolean operators and targeted keywords. Stage 3 (Articles filtering) applied predefined inclusion and exclusion criteria to identify studies aligned with the research objectives. Stage 4 (Cleaning process) consisted of verifying metadata accuracy and organising records using Mendeley and manual checking to remove inconsistencies. Finally, Stage 5 (Synthesis & Reporting) integrated both quantitative and qualitative findings to address the research question, with thematic coding conducted in ATLAS.ti.

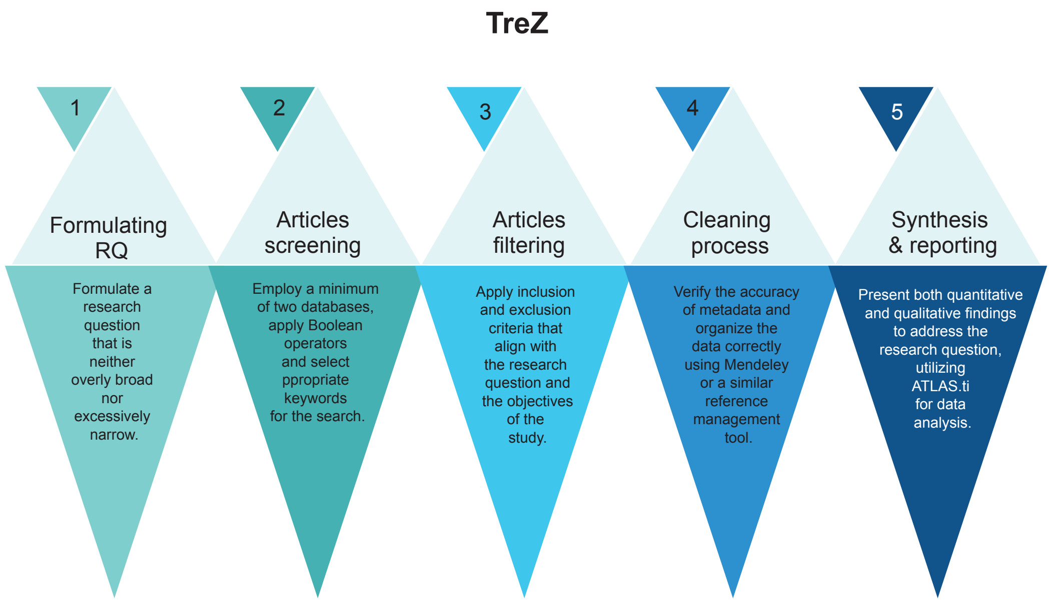

Figure 1: Thematic Review FlowZ (2024)

As illustrated in Figure 2, the database search initially yielded 40 records: Scopus (n = 11), Web of Science (n = 7), and ProQuest (n = 22). Duplicate records (n = 2) were removed, leaving 38 unique studies for screening. Titles and abstracts were independently reviewed by two researchers according to the inclusion and exclusion criteria, and full texts of 27 eligible articles were retrieved for detailed assessment. Discrepancies were resolved through discussion, and inter-rater reliability, measured using Cohen's Kappa coefficient (κ = 0.85), indicated almost perfect agreement according to Landis and Koch's (1977) benchmark scale. A total of 25 papers met all criteria and were included in the thematic analysis.

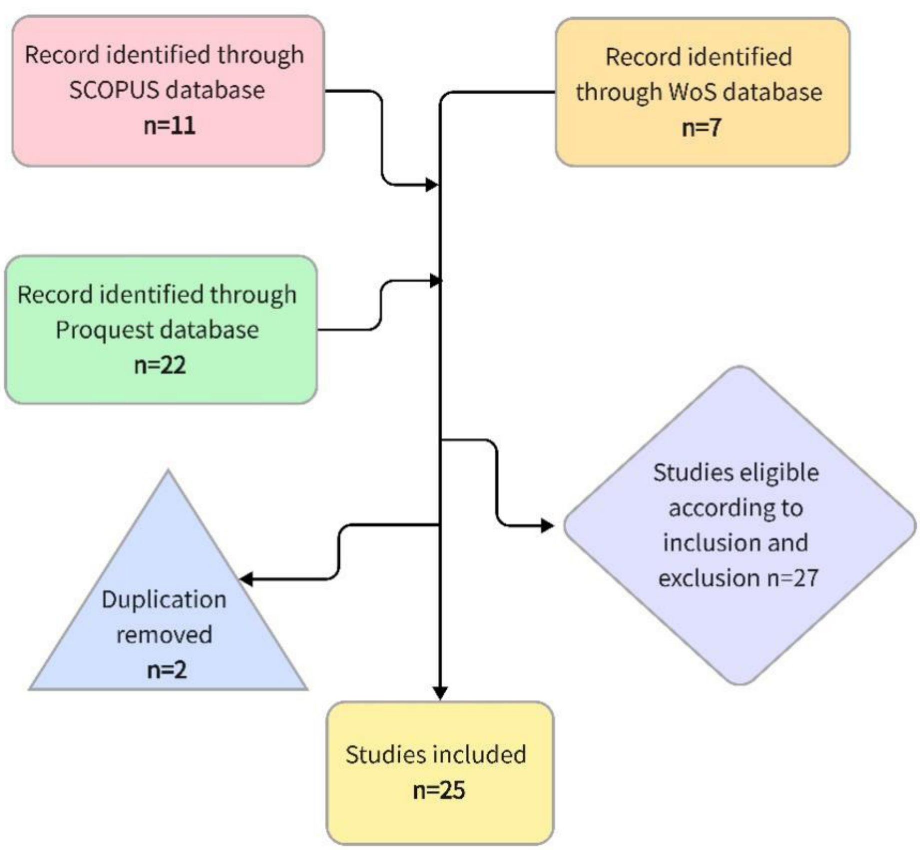

Figure 2: Inclusion and Exclusion criteria

Data processing included removing heavy papers and ensuring metadata accuracy, among other things. Twenty-five papers were exported from Mendeley to ATLAS.ti to answer the question: What are the design factors and application perspectives for increasing satisfaction with smart indoor gardens for older adults? The results of this study are divided into two categories: quantitative and qualitative. The quantitative part will obtain information from a numerical point of view, such as charts, tables, and statistics, while the qualitative part will generate themes from the selected papers. The review highlights relevant elements, features, future trends and many other findings about the topic, providing a window into the future path of this research.

Results and Discussion

This thematic analysis provides an overview of the development of smart indoor gardens in the last decade at home and abroad. The selected papers reveal the great potential of smart gardens in helping older people slow down cognitive decline and enhance quality of life.

Quantitative Findings

The year of publication, the location of the study and the distribution of topics were used to examine trends that reflect the current development of indoor and outdoor gardens in urban areas. As shown in Figure 3, the highest number of papers was published from 2016 to 2024, especially in 2021, and then gradually decreased, partly due to policies related to the COVID-19 pandemic.

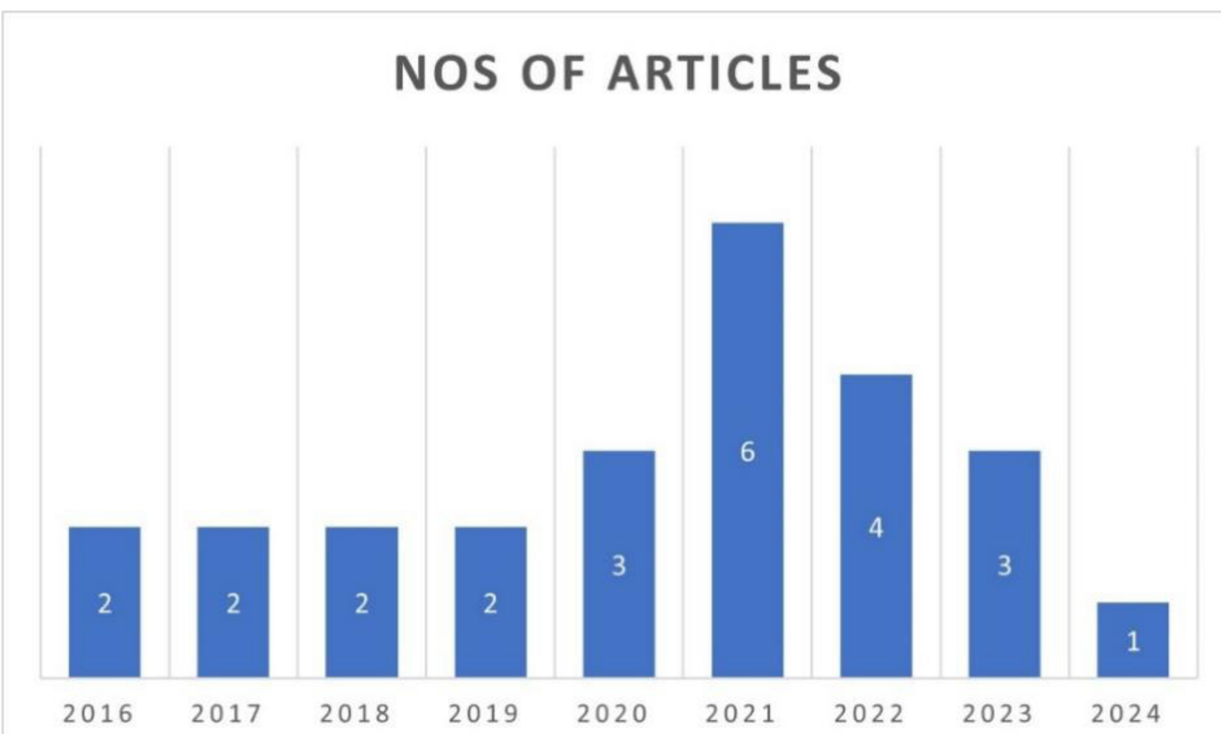

Figure 3: A Breakdown of Articles by Year of Publication

The authors were more interested in the location of the study than the authors' affiliation, as this was the focus of the researchers' attention. In particular, the focus is on developing smart gardens in urban areas, so most of them are in more economically developed countries, as shown in the figure 4. Figure 4 depicts the distribution of countries or regions studied. Among the number of papers, smart gardens are prevalent in Asia and the UK, especially in China.

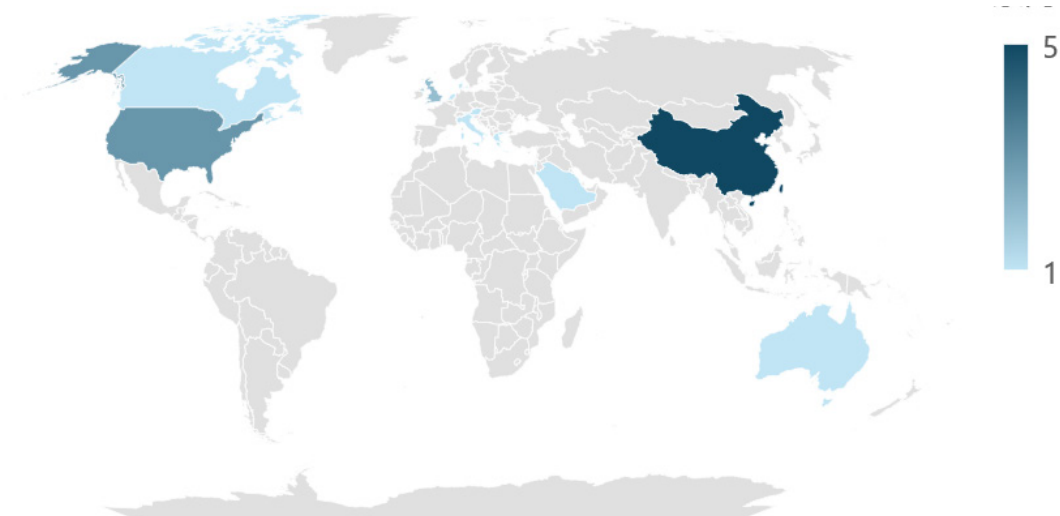

Figure 4: Geographical Dispersion on the Article Published from 2016-2024

In Figure 4, papers from China and the UK appear most frequently, with five and three publications respectively. The UK is a developed country with more rapid development of urban processes, so the research contexts are all in urban areas, focusing on the attitudes of older people in urban areas towards indoor and outdoor gardens (Macintyre et al., 2019) and the sustainable development of edible gardens (Haedicke, 2018) and the impact on emotional well-being (Xu et al., 2023). China includes mainland China, Hong Kong and Taiwan, Hong Kong is a high-density city with a high population density, and more attention has been paid to modelling the use, perception (Lau et al., 2021) and accessibility of green spaces for older people in the city (Gong et al., 2016). However, Taiwan is more concerned about applying smart technologies in smart indoor gardens (Ku et al., 2022; Tseng et al., 2020), which is also due to the different geographical environments.

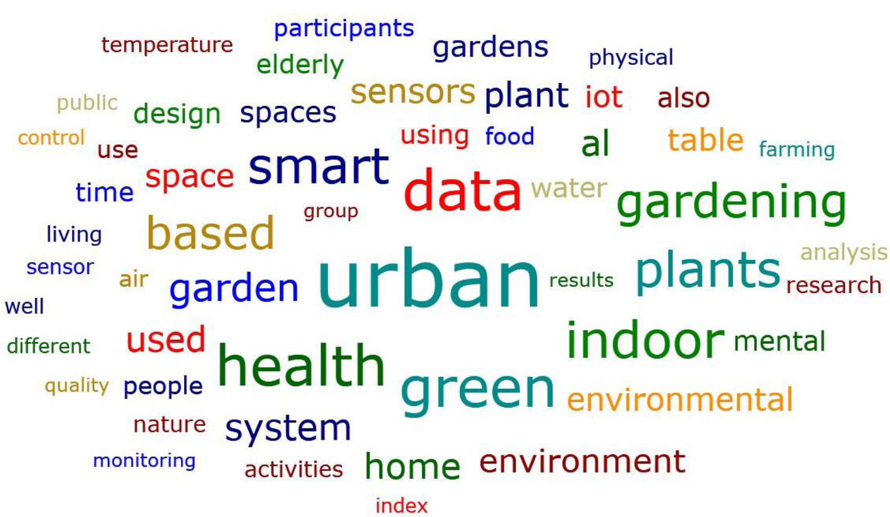

Figure 5: Word Cloud Generated from 25 Articles in ATLAS.ti

Smart indoor gardens show potential for improving urban older adults' quality of life and health. According to the word cloud analysis generated by ATLAS.ti (Figure 5), the keywords "urban", "health", "smart", "data" and "green" show the core themes of design concerns. Introducing smart gardens for the urban elderly, who have limited living space, can provide them with a sense of the natural environment, alleviate the stress of urban life, and promote mental health. The high frequency of smart technology and data monitoring in the word cloud indicates its importance in the smart garden. By monitoring plant growth and environmental parameters such as temperature, humidity, and air quality through sensors, the system can be automatically adjusted to provide an ideal plant growing environment. This convenient and automated management reduces the burden of caring for plants for the elderly and enhances their satisfaction. The keywords of the environmental control function, such as “temperature”, “air quality” and “water”, also highlight the precise control of plant growing conditions. This design meets the needs of the elderly for simplicity and modest maintenance. Meanwhile, the words “elderly” and “group” in the word cloud suggest the importance of social interaction. In this study, “elderly” refers to individuals aged 60 years and above, in line with the United Nations’ demographic criteria and WHO’s earlier statistical usage (UN, 2019; WHO, 2002). While recent WHO frameworks emphasise healthy ageing based on functional ability rather than chronological age (WHO, 2020), the ≥ 60-year threshold was adopted to ensure comparability with existing literature. Smart gardens can provide social support to the elderly through shared planting experiences and online interactions, further enhancing satisfaction.

In summary, the papers studied a variety of topics related to urban gardens, with the most attention paid to smart technology and data monitoring. The goal was to balance technology and humanity through design and provide an emotionally rewarding living space for the urban elderly population, with convenience, health, and interactivity at its core.

Qualitative Reporting

This study reviews existing publications and identifies key design elements and industry trends in smart indoor gardens relevant to the needs of older adults. However, because it is an emerging industry, it does not address the future direction of the industry. After several rounds of research, the initial codes were documented, merged, and categorised. As this study covered aspects extensively discussed and investigated by the researcher, codes that were rarely used and could not be categorised into any theme were removed. In the end, five central themes emerge from literature (Figure 6): (1) user-centred design and accessibility, (2) multisensory and emotional well-being, (3) technological integration and automation for enhanced usability, (4) interaction and community engagement, and (5) sustainability and environmental impact. Each theme is examined in detail, with results from outside the theme or assessment paper cited as needed for description.

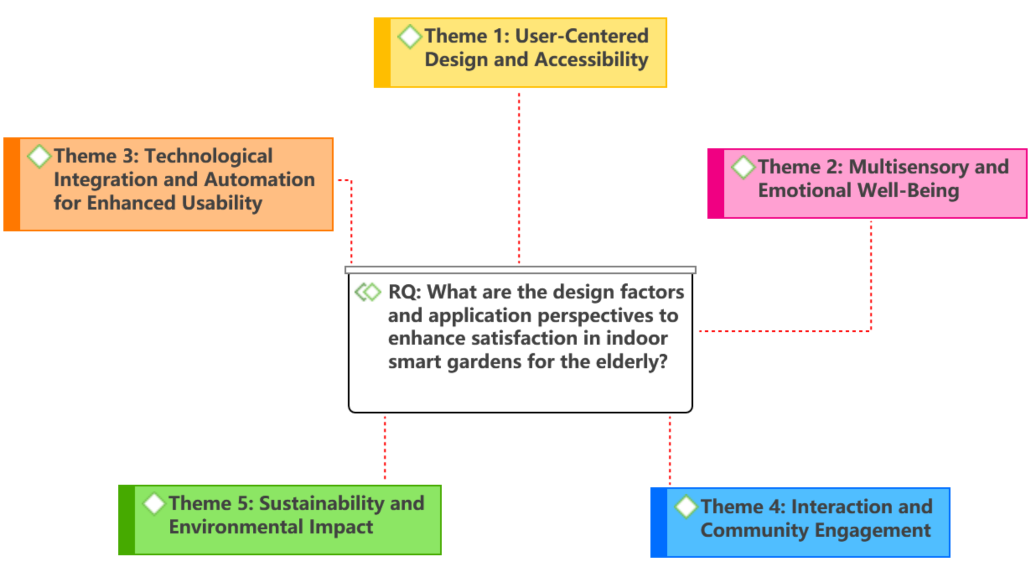

Figure 6: Overall Themes to Answer the Research Question

Theme 1: User-Centred Design and Accessibility

User-centred design and accessibility are crucial role in ensuring that older users can participate in smart garden activities with minimal stress. Gong et al. (2016) highlight the importance of designing accessible green spaces in high-density cities like Hong Kong, China to promote physical activity for older people, while Zschippig and Kluss (2016) on the other hand, focus on how smart gardens can be integrated into environmental assisted living systems to create adaptive environments that promote active aging, enabling older people to live independently and garden comfortably in their homes without being limited by indoor space. Particularly as older people's mobility space declines and mobility decreases, an smart indoor garden that can supply fresh organic produce on time promptly would be more beneficial to older people's physical health. Tseng et al. (2020) designed an interactive indoor gardening game. The reason for transferring therapeutic horticultural activities from the outdoors to the indoors was to improve the safety of people living with dementia and to show that accessible and cognitively responsive interfaces enhance cognitive function and engagement in people with dementia. Macintyre et al. (2019) emphasise the importance of spatial accessibility, stating that factors such as proximity and convenience are crucial for older people's participation in horticultural activities, due to the decline in physical functioning of older people, there is a decrease in accessibility to public green spaces, therefore, creating private gardens are equally important.

These studies show that smart indoor gardens can benefit older users by optimising the humanisation of products through a user-centred design approach. Accessible designs, such as interactive games or spatial layouts, can reduce the physical and cognitive barriers that older people encounter in gardening activities, thereby increasing their participation.

Theme 2: Multisensory and Emotional Well-Being

The multi-sensory design significantly enhances the attractiveness of smart indoor gardens and the emotional well-being of older people in indoor gardens. It has been shown that attractive and well-maintained environments are associated with reduced stress and increased satisfaction among older residents (Heród et al., 2024). Bitterman and Simonov (2017) discuss how multi-sensory elements in pocket gardens can reduce stress, such as enhancing satisfaction through sensory elements such as natural sounds and aromatic plants, which are important design considerations. Also, pocket gardens can help residents overcome density, lack of open space and environmental stress in urban environments. Internet surveys and physiological experimental parameters have shown a clear preference for the sound of birdsong and fountains, as well as the smell of floral tea mixtures, which can be similarly applied to the design of smart indoor gardens in order to improve user satisfaction and quality of life. Ambrose et al. (2020) emphasise the emotional benefits of horticultural activities, stating that they have a significant effect. The average net impact of gardening activities was higher for growing vegetables than for growing ornamentals. Similarly, Zhang et al. (2021) describe the 'eco-therapeutic' benefits of home gardens, demonstrating their ability to reduce psychological stress and increase emotional stability during periods of isolation. Natural sounds, vegetation colours and shapes, and plant scents from home gardens allow for close contact with nature through the sensory organs and the release of negative emotions and stress from mental disorders through horticultural activities. Lee and Park (2021) examined biophilic design elements preferred by older adults, suggesting that nature's sensory connections can significantly enhance psychological well-being. Biophilic design, which investigates the effects of natural environmental properties such as light, air, colour, materials and plants on human physiology and psychology, is a spatial design strategy that seeks to improve the personal experience that occurs when interacting with these properties ('Biophilic Design', n.d.) and proposes to promote sensor and device combinations by type to promote a satisfying experience for older people in the home. Xu et al. (2023) investigated the relationship between urban environments and psychiatric symptoms by mining data from over 150,000 participants in UK banks. They found that accessibility to green space was negatively correlated with anxiety disorders, as a way of demonstrating the impact of indoor and outdoor environmental features of urban living on the emotional well-being of older people.

These studies suggest that incorporating multisensory and biophilic elements into smart indoor gardens can provide therapeutic benefits that support older adults' mental health and emotional needs. In addition, the presence of plants and natural elements can evoke positive memories and enhance cognitive functioning, especially in individuals with cognitive impairment (Hsieh et al., 2022; Lee & Park, 2020). However, linkages to technology and service areas are needed to enhance the natural experience of residential environments for urban dwellers in high-density populations.

Theme 3: Technological Integration and Automation for Enhanced Usability

The design should prioritize usability and ensure that older people can interact with the garden without causing physical stress. Technology integration and automation are essential for improving usability and play a key role in creating convenient and enjoyable smart indoor gardens. This includes considering ergonomics in the layout and incorporating smart technologies to automate tasks such as watering and monitoring plant health, thereby reducing the cognitive burden on the user (Mackensen et al., 2019). In addition, integrating smart home technologies can enhance the overall experience of indoor gardening. Systems utilizing the Internet of Things (IoT) can provide real-time data on environmental conditions to enable optimal growing conditions, whilst also enabling older users to use the technology user-friendly (Da Mota et al., 2022). This technology supports the development of a sense of independence and control, which is crucial for older adults (Wang, 2023). Chakraborty et al. (2022) and Min and Park (2018) discuss IoT-based smart gardening systems that automate irrigation and lighting, reducing manual labor and making gardening easy for older people with limited mobility. Zuniga et al. (2022) proposed sensor-equipped "smart plants" as an economical solution for environmental monitoring, improving usability and indoor environmental quality. Kim et al. (2020) demonstrated that an indoor garden monitoring system based on IoT sensors can improve air quality, increase comfort, benefit user health and reduce maintenance requirements. Ku et al. (2022) and others design indoor planters based on AI IoT for growing edible mints in office environments. The smart device monitors and controls the growth of the planters by deploying multiple AI IoT sensors. The cloud-based service platform provides an inference engine and a data database with multiple triggers. It discusses eight growth states of edible mint with different light, photometric exposure, and moisture content to provide a practical technical solution to meet the needs of people consuming mint in the restricted environment of a high-rise indoor environment. Akintola et al. (2024) incorporate smart technologies such as sensors to create smart plants with mobile wheels to create smart plants that utilize natural attributes to improve efficiency and usability and to monitor the environment to some extent. Suggestions are made for future smart indoor gardens where smart prototypes can be further improved by integrating thermal arrays, air quality sensors and other sensors that provide information about the indoor environment.

Together, these studies highlight the potential of technology integration such as IoT and AI to support and maintain gardening. By integrating more sensors and better interactions to provide the necessary care functions and environmental feedback, plants can be made more environmentally aware and personalized, reducing the cognitive load on older people and enabling them to enjoy gardening activities more easily.

Theme 4: Interaction and Community Engagement

High-tech indoor gardens can facilitate the growing of fresh produce throughout the year, improving dietary intake and engaging older users in meaningful activities (Vlasakker & Veen, 2020). Social engagement and a sense of community belonging are critical to older people's well-being and satisfaction with indoor gardening. Boffi et al. (2021) demonstrated how collaboratively designed community gardens can encourage active aging and enhance social interaction and a sense of belonging. Meanwhile, in-depth interviews with older adults identified specific connections between their needs and design elements, such as expectations for privacy protection, aesthetic value, and more water elements. Haedicke (2018) describes a community garden project incorporating storytelling that deepened social connections among participants and gave the community a unique identity. Lau et al. (2021) study the interrelationship between perceptions and use of urban green spaces in highly populated areas, where the development of smart indoor gardens becomes a possibility to improve the quality of life of urban seniors due to the limited land resources and at the same time the declining accessibility of urban green spaces for aging. Haedicke (2018) and El Khateeb et al. (2023) similarly emphasize the collective gardening activities to support interactions. El Khateeb et al. (2023) pays particular attention to the impact of gender in social gardening to help city authorities create an equitable and inclusive environment. Arof et al. (2020) propose several design elements for creating biophilic cities, one of which is to expand the scenarios for the use of smart indoor gardens by growing edible fruits and vegetables to promote organic markets and community engagement and increasing the participation of older adults.

The social significance of horticulture cannot be ignored. Involving older people in community gardening activities can promote social interaction and reduce feelings of isolation, common in this group (Park et al., 2016). These findings suggest that indoor gardens that facilitate group activities or shared experiences can increase satisfaction and foster a sense of community among users. By engaging older adults in the design and management of indoor gardening spaces, social cohesion can be enhanced, and supportive community networks can also be built.

Theme 5: Sustainability and Environmental Impact

Sustainability and environmental impact are important considerations when designing smart indoor gardens for older adults. Halgamuge et al. (2021) discuss the sustainability benefits of vertical smart garden systems in urban environments, enabling water and energy-efficient practices through the Internet of Things (IoT) to reduce resource consumption and promote environmentally friendly planting. Vertical gardens, which allow plants to be grown vertically stacked in high-rise buildings or indoor environments, can increase productivity while expanding food security in urban environments under limited circumstances. Mihailović et al. (2023) emphasise the role of smart indoor gardens in urban agriculture, noting their potential to support sustainable food production in limited urban spaces. smart indoor gardens allow for year-round planting, significantly increasing food production, improving environmental sustainability, and enhancing human health in urban areas. Cerro (2022) highlights the environmental benefits of indoor gardening, demonstrating how smart garden systems can contribute to environmentally friendly living. For example, hydroponic growing saves energy and reduces emissions, reduces the carbon footprint of food transport and digests food waste to promote sustainable recycling, amongst other sustainable production methods. Ray (2017) reviewed the use of the IoT in smart agriculture, highlighting sustainable practices for resource conservation and efficiency gains, which can be applied to indoor gardens, and identifying their potential for older users.

These studies show that smart gardening solutions prioritising energy and water conservation offer older people responsible ways to engage with nature indoors and are guided by design principles such as reduced material use, modular design to enhance the lifecycle of installed products and the use of green materials, guided by the 4R1D principles of green design, in line with broader sustainable development goals.

To facilitate a clearer understanding of how the five identified themes interrelate from a design decision-making perspective, a conceptual diagram (Figure 7) was developed. This visual representation extends beyond the thematic listing in Figure 6 by mapping the logical and functional connections among the themes.

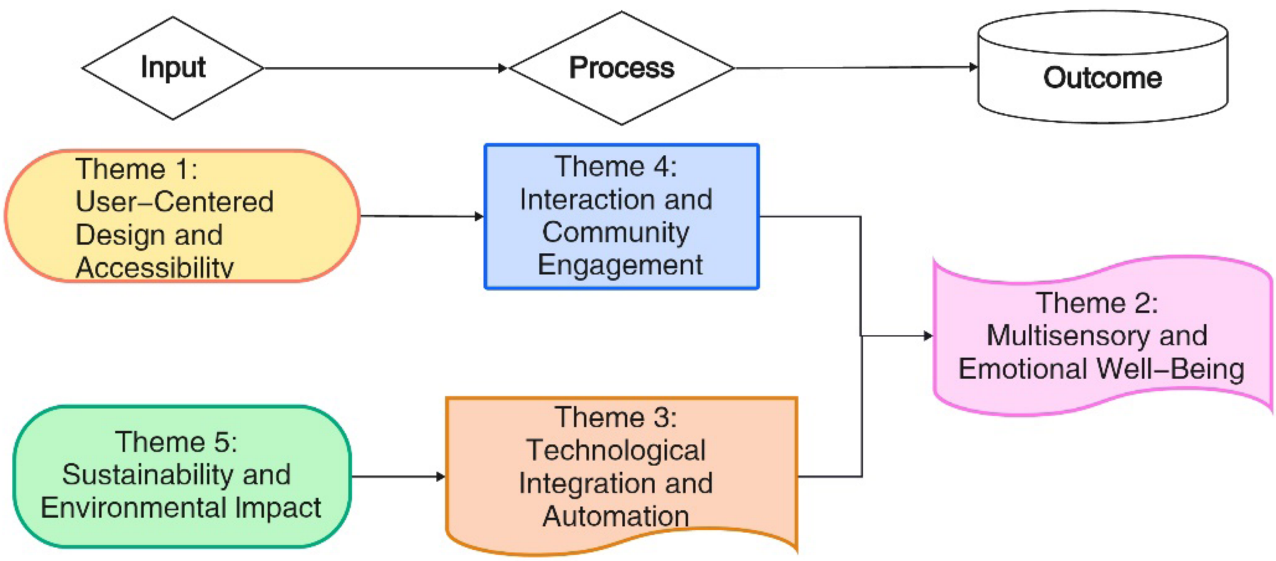

Figure 7: Design Decision-Making Framework for the Five Themes

The framework organises the themes into three sequential stages—input, process, and outcome—reflecting their functional roles in guiding the design of elderly-friendly indoor smart gardens. Themes 1 (User-centred design and accessibility) and 5 (Sustainability and environmental impact) act as foundational inputs, informing the development of process-oriented themes. Themes 3 (Technological integration and automation) and 4 (Interaction and community engagement) constitute the core design processes, enabling functionality, social participation, and usability. These processes ultimately contribute to Theme 2 (Multisensory and emotional well-being), which represents the intended user experience outcome.

The sequential flow from *input* through *process* to *outcome* reflects a logical progression in SIG design for elderly users. Foundational design principles (Themes 1 and 5) inform interactive and technological processes (Themes 4 and 3), which in turn enable enriched sensory and emotional experiences (Theme 2). This integrated framework offers a decision-making guide for designers, technologists, and policymakers, ensuring that the five thematic areas are not treated in isolation but as interconnected components of a unified design strategy.

The qualitative reporting provided an in-depth exploration of five thematic areas influencing the design and implementation of aging-friendly SIGs. While these themes offer rich conceptual insights, their value is maximised when translated into actionable guidance that can directly inform practice. Therefore, the following section distils these thematic findings into a practical recommendation's checklist tailored to key stakeholders with that includes designers, technologists, and policymakers to support evidence-based decision-making and targeted interventions.

Practical Recommendations for Key Stakeholders

Building on the thematic insights presented in Section 3.2, the following checklist synthesises the key findings into actionable recommendations for stakeholders involved in the design, implementation, and policy development of elderly-friendly indoor smart gardens. These recommendations aim to translate the qualitative themes into practical strategies that can guide designers, technologists, and policymakers in enhancing accessibility, usability, emotional well-being, community engagement, and sustainability within such systems, shown in Table 2.

Table 2: Practical Recommendations Checklist

Stakeholder	Key Recommendations
Designers	• Apply inclusive and universal design principles to ensure accessibility. • Integrate biophilic and multisensory features (e.g., plant scents, natural sounds). • Develop modular, space-adaptable layouts. • Ensure interfaces are intuitive and require minimal learning.
Technologists	• Deploy IoT-based environmental monitoring (e.g., soil moisture, air quality). • Automate routine tasks including watering, lighting, and nutrient management. • Implement AI-driven recommendation systems for personalized plant care. • Ensure compatibility with existing smart home systems.
Policymakers	• Embed SIGs in urban ageing and health promotion policies. • Provide subsidies and tax incentives for SIGs adoption in eldercare facilities and homes. • Support community-based SIG programmes to enhance social participation. • Establish sustainability and environmental performance standards for SIGs design.

The checklist summarises targeted actions for designers, technologists, and policymakers, based on the five thematic areas identified in the thematic review. Each recommendation is intended to facilitate the integration of user-centred design, technological innovation, and sustainability considerations into SIG practice.

Conclusion

This study aimed to uncover the design factors associated with increasing the satisfaction of older user groups with smart indoor gardens and application prospects. The authors found that the factors that enhance satisfaction with smart indoor gardens for older adults are multifaceted and require a combination of accessible design, sensory interaction, automation, community involvement, and sustainability. These factors are critical to creating smart products that meet the physical needs of older users and enhance their mental health. This review provides a comprehensive analysis of the five themes, showing the interrelationships between design, technology, emotional well-being, and sustainability in a holistic manner, contributing to the satisfaction of older users with smart indoor gardens. User-centred features, such as cognitively friendly interfaces and assistive technologies, conveniently support older people's participation; multisensory elements meet emotional needs. Automation reduces the maintenance difficulty, and community-oriented design promotes social interaction and enhances a sense of belonging. Finally, sustainable practices improve environmental impact and appeal to environmentally conscious users. These insights guide developing age-friendly smart garden systems that support individual well-being and environmental sustainability.

The practical recommendations presented in Section 3.3 translate these thematic insights into stakeholder-specific actions, enabling designers, technologists, and policymakers to make informed decisions that address the needs, preferences, and well-being of older adults. In doing so, SIGs can serve not only as productive horticultural systems but also as platforms for therapeutic engagement, community interaction, and environmental stewardship.

In conclusion, increasing satisfaction with smart indoor gardens for older adults requires an integrated approach that combines aesthetic appeal, functional design, technology integration, and social engagement. By integrating these factors, creating age-friendly smart indoor gardens has the potential to not only fulfil the physical and mental needs of older users but also to improve their quality of life significantly. This study's results help identify some suggested directions for future research.

Research Contribution and Limitations

This study identifies key design factors that enhance older adults' satisfaction with smart indoor gardens. Firstly, it enriches smart gardening methodologies by integrating inclusive design principles, automation technologies, community-driven approaches, and sustainable practices as foundational elements to create elderly-friendly gardening environments. Secondly, it addresses the research gap in smart gardening for older adults by offering tailored design strategies to designers, engineers, and policymakers. Finally, this study examines the potential mental and emotional health benefits of smart gardening for older adults, particularly those with restricted outdoor activities, offering practical design guidelines for aging societies.

It is also important to acknowledge that older adults are not a homogenous group but rather exhibit considerable diversity in terms of physical mobility, cognitive capacity, digital literacy, and cultural background. While the present review primarily focused on identifying overarching design factors and application perspectives, future research should explore these heterogeneities in greater depth to inform more tailored and inclusive design strategies for smart indoor gardens. Principles of inclusive and universal design, which aim to accommodate users with varying abilities, represent promising directions for subsequent studies.

Practical Contributions

Smart indoor gardens represent a burgeoning area within the domain of urban agriculture. Urban agriculture offers significant social benefits, such as improved access to fresh food, enhanced social cohesion, and the promotion of greener, more liveable environments, as well as environmental advantages, including cleaner production methods, reduced food miles, and mitigation of the urban heat island effect (Vlasakker & Veen, 2020). While indoor gardening may not directly impact the urban environment, gardens utilizing clean and efficient hydroponics can enhance indoor spaces by introducing fresh vegetables, herbs, and plants into older adults' living areas, fostering physical and mental well-being through planting and caregiving activities, which is particularly beneficial for those with limited outdoor mobility. Additionally, these gardens provide opportunities for social interaction, fostering greater social cohesion and contributing to the mental well-being of older adults. Enhancing the design elements of smart indoor gardens through innovative industrial design practices can significantly improve older adults' quality of life and overall satisfaction.

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References

Akintola, A., Liyanage, M., Machado, R., Norbisrath, U., Nurmi, P., & Flores, H. (2024). Smart Plants on Wheels: Enhancing Indoor Productivity Using Smart Plants and Autonomous Ground Drones. *IEEE Pervasive Computing*, *PP*, 1–8. https://doi.org/10.1109/mprv.2024.3416677

Ali@Yaacob, W. N. A. W., Hussain, N. H. M., Nayan, N. M., Abdullah, M., & Teh, M. Z. (2022). The Preferences and Requirements of Green Garden Retirement Care of the Elderly: Case Study at RSK Taiping, Perak, Malaysia. *Planning Malaysia*, *20*. https://doi.org/10.21837/pm.v20i21.1113

Ambrose, G., Das, K., Fan, Y., & Ramaswami, A. (2020). Is Gardening Associated with Greater Happiness of Urban Residents? A Multi-Activity, Dynamic Assessment in the Twin-Cities Region, USA. *Landscape and Urban Planning*, *198*, 103776. https://doi.org/10.1016/j.landurbplan.2020.103776

Arof, K. Z. M., Ismail, S., Najib, N. H., Amat, R. C., & Ahmad, N. H. B. (2020). Exploring Opportunities of Adopting Biophilic Cities Concept into Mixed-Use Development Project in Malaysia. *IOP Conference Series: Earth and Environmental Science*, *409*(1), 012054. https://doi.org/10.1088/1755-1315/409/1/012054

Biophilic Design: An Alternative Perspective for Sustainable Design in Senior Living. (n.d.). *Perkins Eastman*. Retrieved 14 November 2024, from https://www.perkinseastman.com/white-papers/biophilic-design-an-alternative-perspective-for-sustainable-design-in-senior-living/

Bitterman, N., & Simonov, E. (2017). Multisensory Design of Pocket Gardens for Reducing Stress and Improving Well-Being, Performance and Satisfaction. *Design Journal*, *20*(sup1), S2418–S2425. https://doi.org/10.1080/14606925.2017.1352755

Boffi, M., Pola, L., Fumagalli, N., Fermani, E., Senes, G., & Inghilleri, P. (2021). Nature Experiences of Older People for Active Ageing: An Interdisciplinary Approach to the Co-Design of Community Gardens. *Frontiers in Psychology*, *12*. Scopus. https://doi.org/10.3389/fpsyg.2021.702525

Braun, V., & Clarke, V. (2013). *Successful Qualitative Research: A Practical Guide for Beginners*. 1–400.

Cerro, C. (2022). Future of Dwelling: Indoor Plants and Produce. *WIT Transactions on Ecology and the Environment*, *260*(2022), 493–502. https://doi.org/10.2495/SC220401

Chakraborty, N., Mukherjee, A., & Bhadra, M. (2022). Smart Gardening: A Solution to Your Gardening Issues. *EAI Endorsed Transactions on Internet of Things*, *8*(30), Article 30. https://doi.org/10.4108/eetiot.v8i30.384

Cosco, T. D., Kok, A., Wister, A., & Howse, K. (2019). Conceptualising and Operationalising Resilience in Older Adults. *Health Psychology and Behavioral Medicine*, *7*(1), 90–104. https://doi.org/10.1080/21642850.2019.1593845

Da Mota, B., Mataloto, B., & Coutinho, C. (2022). Sustainable Gardens for Smart Cities using Low-Power Communications. *2022 IEEE 28th International Conference on Engineering, Technology and Innovation (ICE/ITMC) & 31st International Association for Management of Technology (IAMOT) Joint Conference*, 1–7. https://doi.org/10.1109/ICE/ITMC-IAMOT55089.2022.10033155

El Khateeb, S., Saber, M., & Shawket, I. M. (2023). Urban Reflections through Home Gardening; Does Gender Matter? *Ain Shams Engineering Journal*, *14*(3), 101885. https://doi.org/10.1016/j.asej.2022.101885

Gong, F., Zheng, Z.-C., & Ng, E. (2016). Modeling Elderly Accessibility to Urban Green Space in High Density Cities: A Case Study of Hong Kong. *Procedia Environmental Sciences*, *36*, 90–97. https://doi.org/10.1016/j.proenv.2016.09.018

H. Miraz, M., Ali, M., & S. Excell, P. (2021). Adaptive User Interfaces and Universal Usability through Plasticity of User Interface Design. *Computer Science Review*, *40*, 100363. https://doi.org/10.1016/j.cosrev.2021.100363

Haedicke, S. (2018). Aroma-Home's Edible Stories: An Urban Community Garden Performs. *Renewable Agriculture and Food Systems*, *33*(6), 542–547. https://doi.org/10.1017/S174217051700028X

Halgamuge, M. N., Bojovschi, A., Fisher, P. M. J., Le, T. C., Adeloju, S., & Murphy, S. (2021). Internet of Things and Autonomous Control for Vertical Cultivation Walls towards Smart Food Growing: A Review. *Urban Forestry and Urban Greening*, *61*, 127094. https://doi.org/10.1016/j.ufug.2021.127094

Heród, A., Szewczyk-Taranek, B., & Pawłowska, B. (2024). Formulating Evidence-Based Design Guidelines for Therapeutic Gardens Tailored to Elderly Populations: A Synthesis of Reminiscence and Preference Studies. *Acta Scientiarum Polonorum Hortorum Cultus*, *23*(2), Article 2. https://doi.org/10.24326/asphc.2024.5303

Hsieh, C.-H., Chen, C.-M., Yang, J.-Y., Lin, Y.-J., Liao, M.-L., & Chueh, K.-H. (2022). The Effects of Immersive Garden Experience on the Health Care to Elderly Residents with Mild-to-Moderate Cognitive Impairment Living in Nursing Homes after the COVID-19 Pandemic. *Landscape and Ecological Engineering*, *18*(1), 45–56. https://doi.org/10.1007/s11355-021-00480-9

Kim, H.-H., Kwak, M.-J., Kim, K.-J., Gwak, Y.-K., Lee, J.-H., & Yang, H.-H. (2020). Evaluation of IAQ Management Using an IoT-Based Indoor Garden. *International Journal of Environmental Research and Public Health*, *17*(6), Article 6. https://doi.org/10.3390/ijerph17061867

Ku, H.-H., Liu, C.-H., & Wang, W.-C. (2022). Design of an Artificial Intelligence of Things Based Indoor Planting Model for Mentha Spicata. *Processes*, *10*(1), Article 1. https://doi.org/10.3390/pr10010116

Landis, J. R., & Koch, G. G. (1977). The Measurement of Observer Agreement for Categorical Data. *Biometrics*, *33*(1), 159–174. https://doi.org/10.2307/2529310

Lau, K. K. L., Yung, C. C. Y., & Tan, Z. (2021). Usage and Perception of Urban Green Space of Older Adults in the High-Density City of Hong Kong. *Urban Forestry and Urban Greening*, *64*(July), 127251. https://doi.org/10.1016/j.ufug.2021.127251

Lee, E. J., & Park, S. J. (2020). A Framework of Smart-Home Service for Elderly's Biophilic Experience. *Sustainability*, *12*(20), Article 20. https://doi.org/10.3390/su12208572

Lee, E.-J., & Park, S.-J. (2021). A Preference-Driven Smart Home Service for the Elderly's Biophilic Experience. *Sensors*, *21*(15), Article 15. https://doi.org/10.3390/s21155108

Macintyre, V. G., Cotterill, S., Anderson, J., Phillipson, C., Benton, J. S., & French, D. P. (2019). “I Would Never Come Here Because I’ve Got My Own Garden”: Older Adults’ Perceptions of Small Urban Green Spaces. *International Journal of Environmental Research and Public Health*, *16*(11), Article 11. https://doi.org/10.3390/ijerph16111994

Mackensen, E., Klose, J., Rombach, A., & Spitznagel, A. (2019). Energy Autonomous Automation of Smart Home Applications using the Example of a Wireless Indoor Smart Gardening system. *2019 IEEE 15th International Conference on Automation Science and Engineering (CASE)*, 1087–1092. https://doi.org/10.1109/COASE.2019.8843000

Maddali, H. T., & Lazar, A. (2020). Sociality and Skill Sharing in the Garden. *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, 1–13. https://doi.org/10.1145/3313831.3376246

Mihailović, B. M., Radosavljević, K., & Popović, V. (2023). The Role of Indoor Smart Gardens in the Development of Smart Agriculture in Urban Areas. *Ekonomika Poljoprivrede*, *70*(2), 453–468. https://doi.org/10.59267/ekopolj2302453m

Min, B., & Park, S. J. (2018). A Smart Indoor Gardening System Using IoT Technology. *Lecture Notes in Electrical Engineering*, *474*, 683–687. https://doi.org/10.1007/978-981-10-7605-3_110

Ray, P. P. (2017). Internet of Things for Smart Agriculture: Technologies, Practices and Future Direction. *Journal of Ambient Intelligence and Smart Environments*, *9*(4), 395–420. https://doi.org/10.3233/AIS-170440

Soga, M., Gaston, K. J., & Yamaura, Y. (2017). Gardening is Beneficial for Health: A Meta-Analysis. *Preventive Medicine Reports*, *5*, 92–99. https://doi.org/10.1016/j.pmedr.2016.11.007

Tseng, W. S.-W., Ma, Y.-C., Wong, W.-K., Yeh, Y.-T., Wang, W.-I., & Cheng, S.-H. (2020). An Indoor Gardening Planting Table Game Design to Improve the Cognitive Performance of the Elderly with Mild and Moderate Dementia. *International Journal of Environmental Research and Public Health*, *17*(5), Article 5. https://doi.org/10.3390/ijerph17051483

van de Vlasakker, P. C. H., & Veen, E. J. (2020). Effects of High-Tech Urban Agriculture on Cooking and Eating in Dutch Nursing Homes. *Sustainability*, *12*(13), Article 13. https://doi.org/10.3390/su12135379

Vassanyi, I., Szakonyi, B., Loi, D., Mantur-Vierendeel, A., & Quintas, J. (2024). Impact of information Technology Supported Serious Leisure Gardening on the Wellbeing of Older Adults: The Turntable Project. *Geriatric Nursing*, *55*, 339–345. https://doi.org/10.1016/j.gerinurse.2023.12.014

World Health Organization. (2002). *Ageing*. https://www.who.int/health-topics/ageing

World Health Organization. (2020). *Decade of Healthy Ageing: Baseline Report*. https://www.who.int/publications/i/item/9789240017900

Xu, M., Lu, S., Liu, J., & Xu, F. (2023). Effectiveness of Horticultural Therapy in Aged People with Depression: A Systematic Review and Meta-Analysis. *Frontiers in Public Health*, *11*. https://www.frontiersin.org/articles/10.3389/fpubh.2023.1142456

Zairul, M. (2021). Opening the Pandora’s Box of Issues in the Industrialised Building System (IBS) in Malaysia: A Thematic Review. *Journal of Applied Science Engineering and Technology*, *25*, 297–310. https://doi.org/10.6180/jase.202204_25(2).0006

Zairul, M., & Zaremohzzabieh, Z. (2023). Thematic Trends in Industry 4.0 Revolution Potential towards Sustainability in the Construction Industry. *Sustainability*, *15*(9), Article 9. https://doi.org/10.3390/su15097720

Zhang, Q., Li, M., & Wu, Y. (2020). Smart Home for Elderly Care: Development and Challenges in China. *BMC Geriatrics*, *20*(1), 318. https://doi.org/10.1186/s12877-020-01737-y

Zhang, X., Zhang, Y., & Zhai, J. (2021). Home Garden with Eco-Healing Functions Benefiting Mental Health and Biodiversity During and After the COVID-19 Pandemic: A Scoping Review. *Frontiers in Public Health*, *9*, 740187. https://doi.org/10.3389/fpubh.2021.740187

Zschippig, C., & Kluss, T. (2016). Gardening in Ambient Assisted Living. *Urban Forestry and Urban Greening*, *15*, 186–189. https://doi.org/10.1016/j.ufug.2015.12.008

Zuniga, A., Motlagh, N. H., Flores, H., & Nurmi, P. (2022). Smart Plants: Low-Cost Solution for Monitoring Indoor Environments. *IEEE Internet of Things Journal*, *9*(22), 23252–23259. IEEE Internet of Things Journal. https://doi.org/10.1109/JIOT.2022.3188475