World Sustainability Series

Walter Leal Filho ·
Amanda Lange Salvia · Eric Pallant ·
Beth Choate · Kelly Pearce *Editors*

Educating the Sustainability Leaders of the Future

Springer

World Sustainability Series

Due to its scope and nature, sustainable development is a matter which is very interdisciplinary, and draws from knowledge and inputs from the social sciences and environmental sciences on the one hand, but also from physical sciences and arts on the other. As such, there is a perceived need to foster integrative approaches, whereby the combination of inputs from various fields may contribute to a better understanding of what sustainability is, and means to people. But despite the need for and the relevance of integrative approaches towards sustainable development, there is a paucity of literature which address matters related to sustainability in an integrated way.

Notes on the quality assurance and peer review of this publication

Prior to publication, the works published in this book are initially assessed and reviewed by an in-house editor. If suitable for publication, manuscripts are sent for further review, which includes a combined effort by the editorial board and appointed subject experts, who provide independent peer-review. The feedback obtained in this way was communicated to authors, and with manuscripts checked upon return before finally accepted. The peer-reviewed nature of the books in the "World Sustainability Series" means that contributions to them have, over many years, been officially accepted for tenure and promotion purposes.

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Preface

If we want to achieve the goal of "Educating the Sustainability Leaders of the Future", we need to start now. This statement is the departing point of this book.

It contains a set of papers presented at the World Symposium on Sustainability in Higher Education (WSSD-U-2022) and has additional inputs which showcase some of the means via which educational opportunities may be created and capitalised upon, with a view to catering for a greater understanding about matters related to sustainable development, which may be used to the advantage of the future leaders: university students.

This book meets a perceived need for a publication on students' engagement on sustainability on the one hand, complemented by examples of initiatives, on the other, which may provide a basis for further works. The book also demonstrates various means via which sustainability messages may be communicated across universities and their audiences. It has the following features:

(a) It outlines some of the methods used in education for sustainability, both using conventional means and distance and online learning, as tools towards educating sustainability experts and leaders of the future.
(b) It describes some of the means which may be used to connect learners and stakeholders through classroom-based discussions about local sustainability concerns.
(c) It illustrates examples of how to use ESD experiences—both in classrooms and outside—to better relate with students.
(d) It showcases tested methods which may be deployed in order to cater for greater involvement of students on sustainability matters.

This book is structured into two parts.

The Part one (*Students' Learning Opportunities and Innovative Teaching Strategies*) presents a set of chapters that explore the connections between innovation and learning, with a strong focus on students' perspectives.

The Part two (*Leadership Through Operations, Engagement and Partnerships*) focuses on examples of the usefulness of leadership in connection with practical operations, also showing the key role played by partnerships.

We thank all authors for sharing their knowledge and their experience by means of their chapters and those colleagues who have contributed to it by assisting with the reviews.

Thanks to its design and the contributions by experts from various areas, this publication provides a welcome contribution to the literature on sustainability in higher education and may hopefully inspire further works in this field.

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Students' Learning Opportunities and Innovative Teaching Strategies

Health at the Margins: Exploration of an Academic Studio Approach to Design for Physical and Mental Resilience in a Sustainable Context

Robert Fryer

1 Introduction

1.1 Background

There are several dynamics underway that are converging to challenge how the US will care for its seniors. It is clear from evidence from existing care facilities and demographics that past approaches are not sustainable and do not work. Among the driving forces are an exploding senior population, the outsourcing of senior care, the high cost associated with this care, the poor conditions of care facilities, and the recent, rapid spread of the SARS-CoV-2 virus that disproportionately impacts senior populations.

Reports show that one-third of all pandemic deaths are either seniors in care facilities or their care providers (Yourish et al. 2020). Grabowski from Harvard states that the leading causes of transmission are the size of the facilities and the number of infected people in the broader neighborhood (Mendoza 2020; Abrams et al. 2020; Hearings before the United States Senate Special Committee on Aging, 116th Congress 2020). The researchers believe that transmission is first occurring from pre- or asymptomatic caregiver and/or visitor to senior.

The opportunity to socialize is a critical component of mental health, which diminishes with age through a lack of mobility and how those with age-related needs are separated from social networks. Furthermore, it is particularly nefarious how SARS-Cov-2 transmission renders socialization dangerous and potentially fatal. Urgent solutions are needed to protect against social isolation while protecting against a disease transmitted through face-to-face interaction.

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What was learned over the past decades could mitigate the spread of diseases like Covid-19 if it was applied in practice. Evidence has been mounting for characteristics and quality of care from room size and configuration, density, building forms, daylighting, to connections to nature both indoors and out. The conventional design developed in the 1970s focused too much on the efficient deployment of institutional care. Studies show that results improve when design simultaneously considers the individual as a whole person, and the care professionals' performance and health.

Sustainable education, research, and design approaches are presenting positive alternatives. However, these findings do not seem to be widely deployed and adopted in either new construction nor the renovation of existing buildings. This article reports on design research and education into these issues, and presents alternative designs. Perhaps more interesting are the areas of overlap between what is beneficial for senior care design and others areas of urgent design needs, specifically open spaces, a connection with nature, urban resilience, and sustainability. The process and work presented here are generated in multiple studios in a graduate program. The process and insight gained can impact the education and success of students as they graduate to be the leaders of tomorrow.

1.2 Social Dynamics

According to a multi-institutional report, "For the first time in history, and probably for the rest of human history, people age 65 and over will outnumber children under age 5" (National Institute on Aging, National Institutes of Health, US Department of Health and Human Services, & US Department of State 2007, p. 6), and the senior population will outnumber all children by 2035 for the first time in history (National Institute on Aging, National Institutes of Health, US Department of Health and Human Services, & US Department of State 2007; US Census Bureau 2018). As a result of such dynamics, the burden of cost for seniors will fall on fewer people while the costs are increasing. Seniors require care that is provided by and, for some, funded by younger demographics. This will require younger populations to pay more than previous generations to provide for others as they near the end of their life. Furthermore, the economic conditions for younger populations do not resemble previous generations' wage growth and living costs at their age as shown by higher levels of student debt, delayed marriage and starting of families, and lower rates of homeownership. It is uncertain if higher costs can be supported by a fewer number of already economically challenged citizens, despite the honorable social responsibility to do so.

Part of this can be explained by cultural shifts over the past century, where the family structure has shrunk over time, from extended, to nuclear, to single parent homes, and where women, the predominant caregivers at home, are choosing or are forced to enter the workforce. As a result, the skills required to care for older relatives are not learned as they once were, and more are, understandably, opting to outsource care. As more families seek care outside the home, access to social and

financial resources is required, which is influenced by socioeconomic forces. The middle class, unable to afford private care yet too wealthy to qualify for assistance, is severely impacted (Bookman and Kimbrel 2011).

As the number of primary caregivers declines, seniors will either find institutional care, or go without. Having no caregivers usually means social isolation. However, isolation can occur within institutional care, too. This creates a need for senior facilities that must be met rapidly.

2 Methodology

Student work was from multiple graduate-level studios, ranging from a 3 credit "mini-studio" with 3 weeks for the project, to thesis with two semesters. The design approach differs significantly differs from conventional studio education in three ways. First, this approach asks students to delay the impulse to start their design with concepts of making and form (a conventional approach) to instead start by undertaking research and follow the recommendations that result. Second, the research is analyzed through a systems thinking process, which can work across scales and conventional disciplinary boundaries to arrive at broader, systems-level analyses and conclusions. This often leads to unconventional solutions that challenge the traditional scope of the architectural domain. Finally, the design approach employs an adaptation of the integral framework in an effort to be more holistic by viewing the design analysis and proposal from multiple viewpoints.

2.1 Research

Students began by understanding the topic through extensive research. They compiled relevant sources and case studies to discover issues over time. Sources included government publications, scientific studies, industry periodicals, etc., and identified key drivers in demographics, published health studies, and evidence-based research regarding state-of-the-art design developments, such as technology and biophilia.

2.1.1 Demographics

Students investigated the relationship between age and size distributions of population classifications at a national scale. Seniors require care that is provided by and, for some, funded by younger demographics. In 1900, the number of people living beyond 85 years of age was approximately 100,000; by 2010 it was 5.5 million; by 2050 it is projected to be 19 million; and it is the fastest growing segment of the population (Institute of Aging 2016). Most senior care (approximately 65%) is

still provided inhouse by the younger members of the family, predominantly women (Institute of Aging 2016).

However, the decreasing rate of homecare has been projected to accelerate. Demographics showed an increase in the number of women in the workforce, and that the senior population will outnumber children by 2035 for the first time in history (National Institute on Aging 2016; US Census Bureau 2018). As a result, more families sought care outside the home, which required access to social and financial resources, which are influenced by socioeconomic forces. The middle class, unable to afford private care yet too wealthy to qualify for assistance, was severely impacted (Bookman and Kimbrel 2011).

According to AARP, 68% of Americans expect to rely on family to provide care (Redfoot et al. 2016). However, given population dynamics, this may not be possible. In fact, this "care gap" is growing. In 2010, there was a family caregiver to senior ratio of 7:1; by 2030, this is projected to be 4:1; by 2050, 3:1 (Redfoot et al. 2016). As the number of primary caregivers declines, seniors will either find institutional care, or go without. Having no caregivers usually means social isolation. However, isolation can occur within institutional care, too.

From this research, students learned about the complex system dynamics of socioeconomics, population change, and caregivers, which created the foundation of a learning scaffold. This information was initially compiled in a point-based outline, and later developed into text.

2.1.2 Understanding the Context of Health

The next layer to the learning scaffold was understanding the context of senior health and its key drivers. Students decided to work with three main research areas: isolation, dementia and biorhythms.

Isolation

Approximately 28% of the 65 + population lived alone in 2010, the majority of which were women (West et al. 2014). Living alone often leads to social isolation, which studies show have negative health consequences. The death of friends and spouses, retirement, moving, and lack of mobility, all contribute to diminished rates of social contact. Humans have evolved to be social, meaning-making creatures, therefore without social contact, mortality risks, obesity, type 2 diabetes, depression and dementia all increase (Cacioppo and Hawkley 2009). Isolation also increases vulnerability to abuse, physical and financial, and LGBT seniors are twice as likely to live alone due to a lack of community support and the tendency to have fewer children (SAGE 2018).

Dementia

The most common cause (60–80%) of dementia is Alzheimer's Disease, which includes memory loss and other cognitive decline (Alzheimer's Association n.d. a). Estimates state that in 2017 5.5 million Americans were living with it; by 2050,

that number is projected to increase to16 million (Alzheimer's Association n.d. b). Among the symptoms, Alzheimer's Disease presents itself as having more-than-age-appropriate difficulty with daily tasks, wayfinding, time and place confusion, difficulty with spatial relationships, and a withdrawal from social activity (Alzheimer's Association n.d. c). Supervision of those with dementia includes limiting their independence and mobility as a protection, however, this negatively impacts one's dignity, confidence, and quality of life, reinforcing the decline of cognitive and physical well-being.

Daylighting and Circadian Rhythms

Risk of dementia can be increased by poor lighting. Biorhythms required for mental and physical health, such as circadian rhythms, depend on being synced with the solar rhythm. When access to daylight is prevented, or artificial lighting does not simulate natural daylighting variability, sleep and mental cognition is impaired (Lighting Research Center at the Rensselaer Polytechnic Institute n.d.). Studies show ambient lighting levels of 2,500 lx during daylight hours in common spaces results in significant improvement in sleep (Calkins 2009), and improving lighting in dining rooms improves food intake (Brush and Calkins 2008).

The students began to connect the dots between these issues and the built environment. The architectural elements of spatial relationships, defining time and place, functional requirements of tasks and circulation, and social spaces were seen as operational in senior health issues. Students wondered how best to define beneficial spatial configurations, and if any research could propose antidotes to health concerns. They also posed the question: could design be re-envisioned to engender well-being, rather than respond to symptoms? This became another layer in their scaffold where they dug further into the built environment research to unearth past, present and future solutions.

2.1.3 Evidence-Based Research

Students found a strong and evolving body of evidence-based research investigating the therapeutic capacity of the built environment. They studied the context of research over time to find published recommendations. The findings were used as opportunities for critical discourse, analysis, and ultimately were applied to their projects. The findings presented in this paper relate to the issues outlined above (isolation, dementia, daylighting and biological impacts) and were explored through multiple scales: from neighborhood, to site (landscape and building relationship), to building (building form, unit size and configuration), and interiors (unit layout).

Senior care design has evolved over time. Students uncovered that originally facilities were designed to provide care based on the efficiency of caregiver performance. The nurse station was a dominant feature, and there were usually 60 "patient" units, within easy reach, organized along monotonous, double-sided corridors. The aesthetic was institutional. This began to change in the late 1970s with the Weiss Pavilion in Philadelphia, informed by the groundbreaking work of Dr. M. Powell

Lawton, who is regarded as a research pioneer into the built environment and dementia. He outlined 5 principles which came to be the foundation of therapeutic goals for such facilities: orientation, negotiability, personalization, social interaction, and safety (Calkins 2003). Their translation into design has since been advanced by further research in lighting and the impact of biophilia.

Students also investigated building forms, and found that, traditionally, they were H, L or T shaped to provide centralized, efficient care (Hiatt 1991). Since then, unconventional formal experiments confirmed simple forms, such as L and T (notably not H) work best for wayfinding. However, these forms can also lead to monotonous corridors that disorient residents. Other research suggests that these building forms, if used in conjunction with varied configurations such as clusters, open spaces and combinations of the two, lead to increased independence, confidence, and social interaction. Studies using the function social density metric (social space area per number of residents) show facilities with higher function social density correlate with increased social activity (Calkins 2009). Students discovered the development of such varied configurations create opportunities for outdoor views, which greatly enhance wayfinding and provide daylight and lighting variability, which have demonstrated mental and physical well-being benefits, and are among the 14 patterns of biophilic design (Browning et al. 2014).

Biophilic design and its effects have become more popular, stretching from traditional Japanese *shinrin-yoku* ("forest bathing") (Ohtsuka et al. 1998) to the development of therapeutic gardens. Health research confirmed there is a beneficial biological response to nature (Kellert et al. 2008; Browning et al. 2014) while surveys of senior care residents showed gardens are a desired feature that impacts psychology (Kearney and Winterbottom 2008). People want to be near nature because it is soothing, alive, meaningful, and helps them sleep better. Students realized that varied configurations, which mark a break from the traditional layout of monotonous corridors and easy to reach units, can actually improve caregiver performance, as wll, by introducing biophilic elements that are shown to improve productivity, and alleviate symptoms of stress and illness. Outdoor access, whether direct or not, became a central issue for students through their analyses. They confirmed that connections with nature are essential to successful senior living facilities.

Students also concluded, based on research, that private rooms should be offered as much as possible (acknowledging equity limits to this proposition), and should be customizable through furniture, art, plants, etc. A general theme that emerged from studies was the need to create home-like atmospheres. Students argued that senior facilities are obligated to be places of therapeutic value, respite, safety, and comfort, but that they are also places to reside, eat, have fun, and find meaning, including opportunities for activity and exploration. The students explored the notion of "home" across scales via a study of Hogeweyk (Dementia Village Associates n.d.; Niek Roozen BV Landscape n.d.), a dementia care village, which expanded the experiences of dignity, independence, freedom and mobility from the level of the room and applied them at the scale of a small village. Residents of Hogeweyk are able to walk outdoor corridors ("streets") lined with stores and cafes to grocery shop

and relax. However, there is only one entrance to the village that is secured, so no resident can wander offsite.

At this point, students concluded, in agreement with much of the research findings, that senior facilities as currently executed are not widely incorporating the latest research. They argued for architects and related professionals to do more.

2.2 Design Approach

2.2.1 Framework

The studio explored a new design framework informed by Integral Theory (Wilber 2005), but adapted to accommodate a more comprehensive design process. Although the components (site inventory, site analysis, design) were not new, the adaptation used the four quadrants of Integral Theory to attempt a more holistic process, an innovation compared to traditional studios. The quadrants are based on the psychological imperative of addressing the whole person for well-being, and were adapted by DeKay (2011) to design, and the studio further adapted them to facilitate a design process that addressed the whole project: subjective, personal experiences; subjective, collective culture; objective measurements of performance; and objective observations of nested systems that impact the project. This can be applied at all scales (individual to global), and cross-scalar drivers and relationships can be identified and addressed through design. The use of a more holistic process, i.e. seeing the project through four unique lenses at multiple scales, opens the possibility to include more dynamics and information, and thus miss or ignore fewer key drivers, approaching a more truly sustainable outcome by eliminating externalities. For example, students designed health-related policy in addition to the site/building design.

2.2.2 Site Research

Students identified potential sites, and the selections varied from adaptive reuse to brownfield sites. These sites were inventoried to capture experiences (beauty, views, feelings); performance (sun path, winds, climate and microclimate); culture (demographics, livability index, public art, etc.); and systems (transportation, stormwater, power, waste, etc.) (Fig. 1).

Students then created guiding principles to help make design recommendations, establish goals, and propose strategies. Example guiding principles are: A safe, comfortable, and healing built environment will enhance the quality of life for the residents (Experience); An energy efficient built environment promotes the well-being and performance of the staff (Performance); Seeing patients and caregivers as one community promotes inclusiveness, interaction, and support (Culture); Respecting planetary boundaries, biodiversity, and striving for zero emissions will add resilience

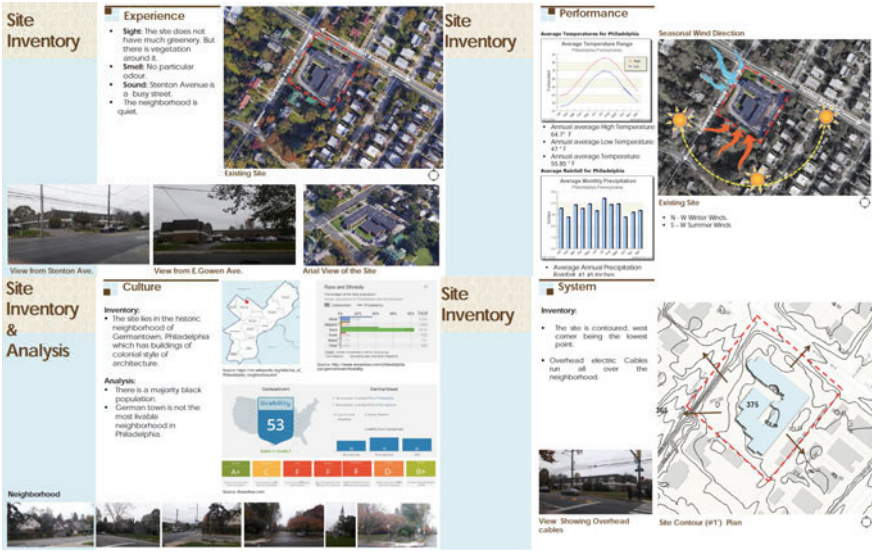

Fig. 1 Site inventory of a project with an existing building to be renovated and reused

(Systems). One student argued for more stakeholder equity in the design process, and held a charrette at a local senior facility to include the residents.

During site analysis, students reflect on their inventory to identify opportunities, challenges and recommendations consistent with their guiding principles. This began their goals and strategies development. Example are: Provide indoor and outdoor spaces that encourage physical and social activity by limiting corridor lengths; include multiple, smaller lounge spaces for interaction; design a walking route outdoors through a therapeutic garden (Experience). Perform better than the EnergyStar EUI for senior care communities benchmark by enhancing daylight, building envelope and natural ventilation (Performance); all social spaces must be 100% ADA accessible (Culture); meet LEED v4 water benchmarks via greywater reuse, low flow fixtures, and raingardens (Systems).

2.2.3 Design Development

Form and Aesthetics

In conducting the design research, opportunities were explored to accommodate the insights from the students' research regarding builing form. Such opportunities are limited, however, when working with renovations to existing buildings and zoning demands, such as FAR requirements and height restrictions. In one case (Fig. 2), however, there was an opportunity to enhance the existing L-shaped form of a building by removing a block (shown by dashed yellow lines) and relocating its program as a

Fig. 2 Site location of one of the study projects with an existing senior care facility. **a** After careful study, the area in the yellow-dashed box was relocated on top of the of the red-dashed L building form, thus following evidence-based recommendations for building forms of senior care facilities; **b** shows an aerial image from the southeast. Removing the block increased solar passive heating and daylighting for the building

third floor on top of the existing 2-story form (shown by dashed red lines). Detailed programming analysis (Fig. 3) led to a reconfiguration of spaces, and also created the opportunity to alter the aesthetics of the building to better fit with its surrounding neighborhood context, which is marked by traditional residential architecture, gabled roofs and dormers.

Although the aesthetics of the final design of the research study (Fig. 4) may not appear to be "innovative", this was not the goal of the research. Instead, the goal was to meet evidenced-based care needs while becoming a visual member of its surrounding community, and to resist the more ego-based formal and aesthetic expressions of designers, or as Roaf put it, "the architectural fantasy that [architects'] main professional contribution to society is in sculptural art" (Roaf 2020, para. 2). This also helped to reinforce the home-like feel, and replace the mid-century institutional aesthetic of the existing structure, both of which are shown to improve care outcomes.

The design study analyzed the floor plans to propose solutions to monotonous corridors by adding social spaces, such as lounges and game/activity areas on each floor. All have the potential to accommodate social distancing requirements to prevent the spread of SARS-CoV-2, when required (Fig. 5). By making the decision to remove the block and relocate the programming spaces to a new third floor, the newly created outdoor space provided the opportunity to increase the functional social density and

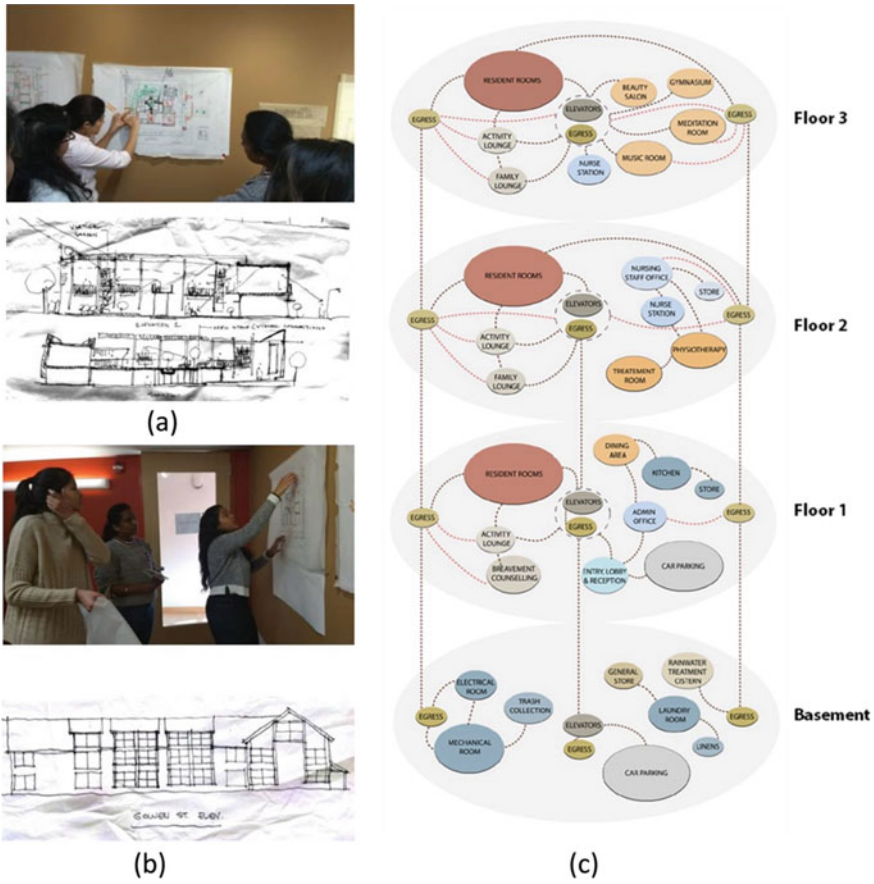

Fig. 3 Design renovation process of program, plan, and elevations. **a** Shows plan revision sketches; **b** shows the development of the elevations to match the local context; **c** shows the revised program by floor to relocate the existing programming formerly in the demolished box

achieve multiple biophilic design objectives, such as a visual connection to nature, presence of water, dynamic and diffuse light, complexity and order, prospect, and refuge.

Another essential element of the formal and programmatic revisions was to consider the residents' care and the care professional's performance and health simultaneously. The change in form and layout provides caregivers with direct access to and views of nature, sunlight, and gardens, which are shown to reduce their levels of anxiety and depression, while improving job satisfaction, productivity, and creativity (Browning et al. 2012). Furthermore, other amenities were added to support caregivers, such as bike racks and showers.

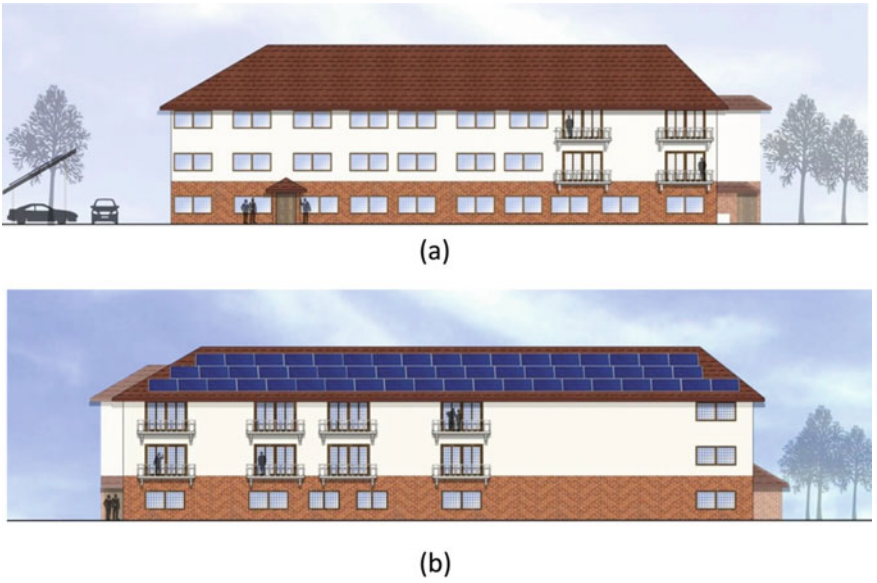

Fig. 4 Revised elevations to match local architectural style and to fit better with the neighborhood. **a** Shows hipped roofs, added balconies, new windows, and brick and stucco façade; **b** shows the southwest elevation with solar panels on the roof

Room Size and Density

The existing building of the design study offered mostly double occupancy rooms, and these did not meet the minimum rooms dimensions of the 2017 National Center for Assisted Living Guidelines (NCAL), nor did they meet minimum dimensions of the Americans with Disabilities Act (ADA). The NCAL requires a minimum of 300 ft^2 for doubles and 225 ft^2 for singles, and the existing rooms provided 192 ft^2 for the doubles, thus not even meeting the guidelines for single occupancy rooms. As a result, the rooms were reconfigured to provide mostly single occupancy rooms (ranging between 260–300 ft^2), with double occupancy rooms provided for couples (ranging between 405 and 562 ft^2), and all ADA requirements were met (Fig. 6). Private rooms and home-like atmospheres also support caregivers because these result in fewer roommate disputes, a very common and stressful dynamic.

All rooms were provided with multiple operable windows for several reasons. First, natural ventilation is essential for fresh air, and this is discussed more later. Second, they provide access to sun and the natural daylighting of spaces. Both of these also support reduced fuel consumption, greenhouse gas (GHG) emissions, and add resiliency to the design. Finally, they provide multiple biophilic design characteristics thus supporting health and well-being.

Senior facilities are to be places of therapeutic value, respite, safety, and comfort, but they are also places to reside, eat, have fun, and find meaning, including opportunities for activity and exploration. While private rooms are meant as places of respite

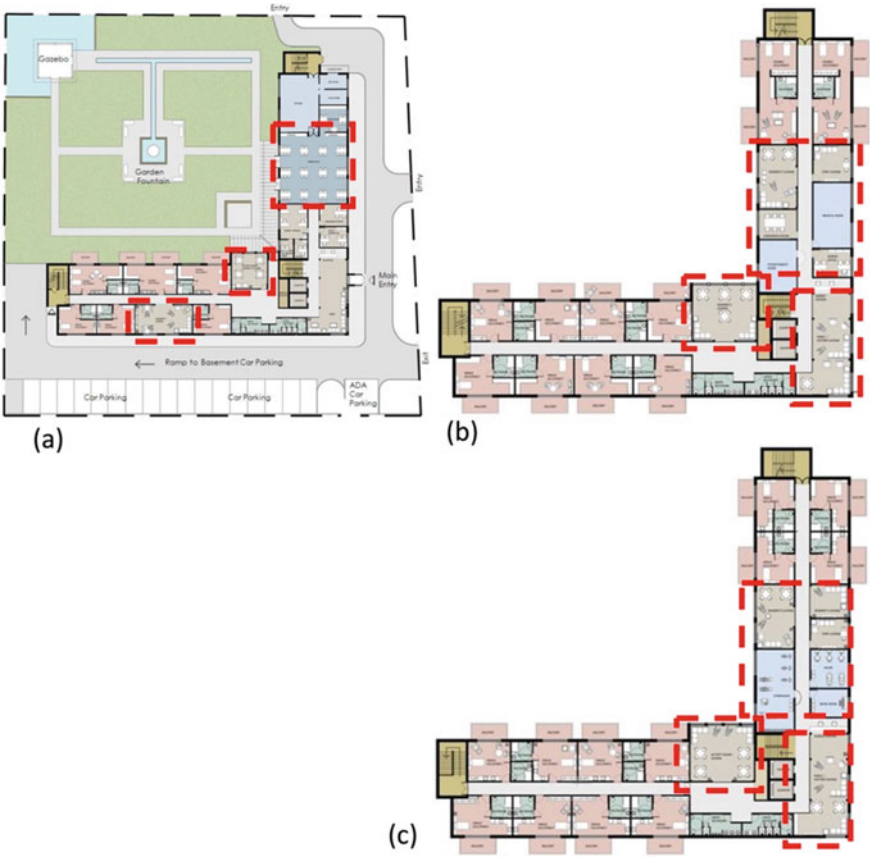

Fig. 5 Floor plans indicating new interior social spaces in red-dashed areas. These were designed as solutions to the existing monotonous corridors, and were replaced with added lounges, game/activity areas, and dining. Each of the spaces can accommodate social distancing requirements. **a** Ground floor; **b** second floor; **c** third floor

and relaxation, isolation is addressed through community gathering spaces. Because of Covid-19, gathering spaces need to be smaller, limiting the number of residents to prevent transmission, and the CDC and others recommended limiting the number of visitors (Centers for Disease Control and Prevention 2020). However, outdoor spaces can be activated as social spaces and can be used for visiting purposes, thus expanding the opportunity for increased social engagement. Outdoor spaces provide multiple benefits, such as promoting mobility, exercise, and a connection to nature and natural systems in spaces where the potential for transmission of SARS-Cov-2 is greatly reduced. This is discussed more later.

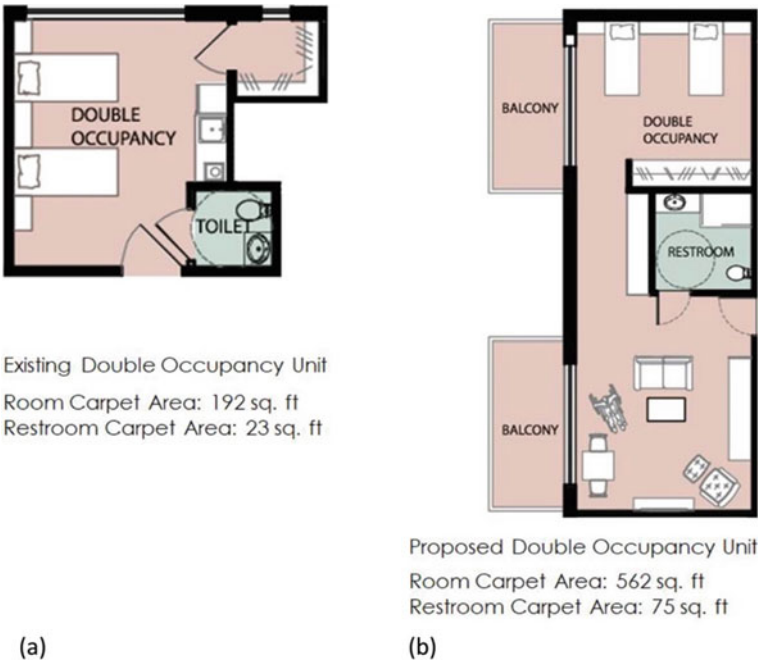

Fig. 6 Before and after redesigned room plans. **a** Existing plan and areas; **b** Revised to meet NCAL, ADA and Covid-19 requirements

Daylighting

To support biorhythms, it essential to provide abundant and appropriate levels of daylighting. Simulations were used to evaluate daylighting performance (IESVE version 2018; Radiance 1998) and energy consumption (Sefaira 2018). For daylighting, simulations were run multiple times per day of the solstices (Fig. 7). Results were compared against targets recommended by the Illuminating Engineering Society (IES) and in senior health studies (Calkins, 2009), and used to refine the design.

Design targets set for daylighting attempted to reach them without artificial lighting. These targets recommend 300–600 lx for private rooms, and up to 2,500 lx ambient lighting in common spaces. Limitations were the orientation and building forms of existing structures, and the need for multiple floors in buildings with deep plans, which must rely on roof access for daylight penetration near the center of the floor plans. Results showed that most rooms, if moved to the edges of floor plans, could meet the targets, and even require glare control for some period of the year. The targets for common spaces were more difficult to reach, and were highly dependent on number of floors and building form of existing buildings. If designing new buildings, building forms should include thinner floor plates to provide access to lighting

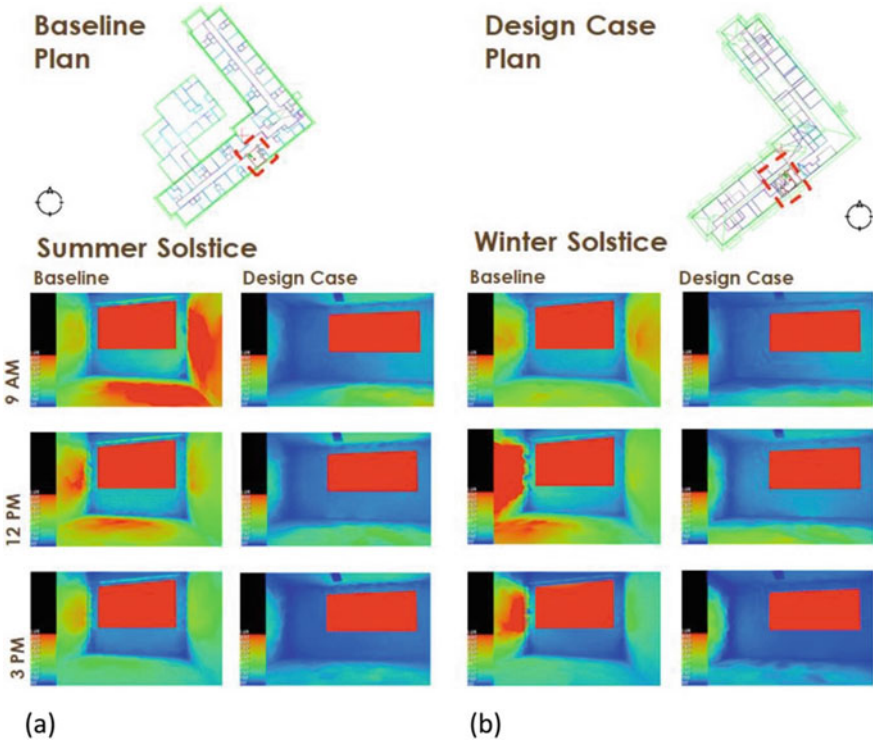

Fig. 7 Daylighting simulations comparing the existing and proposed room changes. **a** Summer solstice; **b** winter solstice

and natural ventilation through wall openings or incorporate daylight access through the roof near the center of deep floor plans.

HVAC Systems and Energy

Thermal comfort is a central concern for older populations as the body's metabolism slows with age. Furthermore, being an airborne virus, SARS-CoV-2 requires higher ventilation rates (use of a direct outdoor air supply (DOAS) system) with higher performance air filtration than standard recommendations (MERV-13 or higher) to help combat its ability to spread. Depending on the climate, thermal comfort and ventilation can be met passively through operable windows for a portion of the year, and operable windows and balcony doors were provided for this reason. Furthermore, the use of operable windows and doors is highly effective in reducing the spread of the coronavirus by reducing the density of any aerosolized viral load that may be present. However, when the climate is outside of the comfort zone, thermal comfort must be met by mechanical systems, which also drive energy consumption, and depending on the energy source used, could also increase CO_2 and other GHG emissions.

For energy consumption, the energy use intensity (EUI) was simulated to establish a baseline for a DOAS system (268 KBTU/sf/yr), then simulations were performed in series to isolate and evaluate specific alterations to the building, such as windows and insulation (Fig. 8), geoexchange (Fig. 9), and finally the use of solar panels. EUI results were compared against benchmarks, such as EnergyStar values for senior care centers, enabling designs to be situated among case studies.

Net zero energy is difficult to achieve. However, the use of energy efficiency methods, such as high R-value insulation in walls and roofs, carefully selected windows, geoexchange DOAS HVAC, and onsite energy can decrease offsite energy demand significantly (down to 55 KBTU/sf/yr for one project), and reduce energy consumption in some cases by half compared to EnergyStar benchmarks (125.5 KBTU/sf/yr) (Energy Star Portfolio Manager 2021).

Social Spaces: Interior and Exterior

As mentioned before, spaces with higher functional social density increase social activity. The architectural tools available to increase the functional social density are indoor and outdoor spaces that are made easier to create with specific formal adaptations to traditional T and L building forms, such as clusters and open spaces.

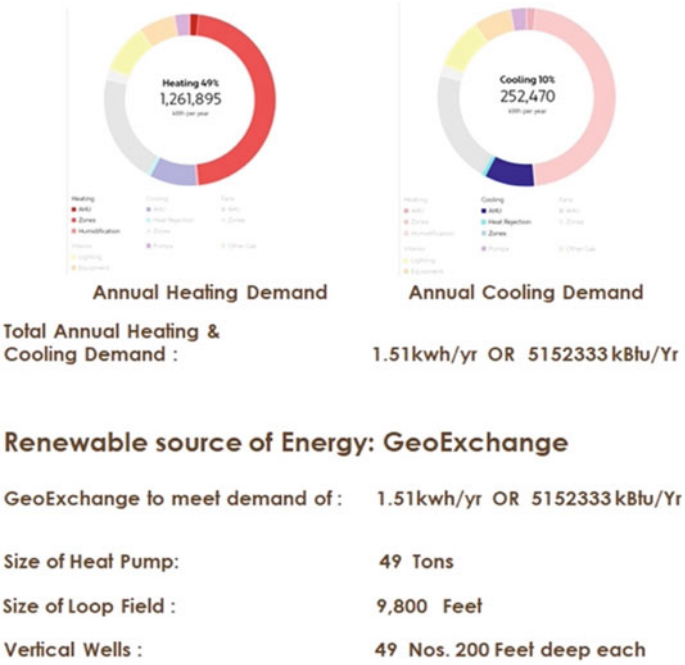

Fig. 8 EUI simulations showing impacts on DOAS system after changing R-values in the walls and roof. At this stage of design, the EUI was reduced from 268 to 196 KBTU/sf/yr. Additional changes (geoexchange and solar panels) and simulations eventually reduced the EUI for this project to 55 KBTU/sf/yr

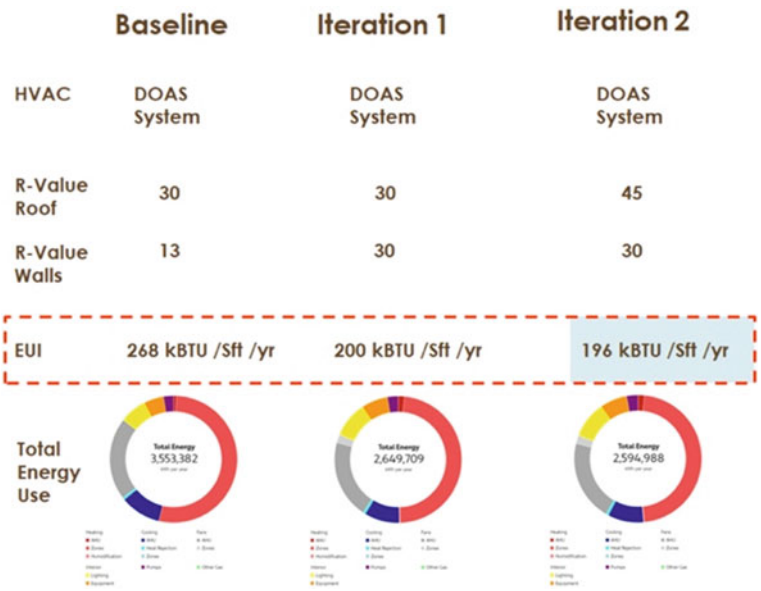

Fig. 9 Simulations showing the impact of a geoexchange system on energy consumption

Furthermore, limitations on the number of visitors are based on the number available spaces for gathering and the area of these spaces to meet social distancing requirements, in essence limiting the functional social density. However, outdoor spaces are permitted for visitation, and can thus be used to expand the number of allowable visitors. Furthermore, spending time outdoors is correlated with lower risk for spreading SARS-CoV-2 and an improved immune system response to Covid-19 because of Vitamin D3 activation, and there are additional wellness benefits to being in nature and gardening (McIntosh 2020).

Designs were developed with these approaches, referring to case studies for guidance. For example, to incorporate biophilic outdoors spaces with wayfinding view corridors from inside, naturalistic compositions were proposed that also promote healing, so garden designs of Gertrude Jekyll were explored and the American Horticultural Therapy Association's (AHTA) therapeutic garden characteristics were applied (Fig. 10) (Hazen 1995). Jekyll's famous garden designs featured a combination of rigid and organic elements that provided a hidden organization over time as the vegetal composition matured. Her designs were known for water features and the layering of vegetation that was carefully chosen for rich colors and textures and different flowering seasons so the gardens could be enjoyed throughout the year. The study's design used Jekyll's approach as inspiration, including a central water fountain, native species for different seasons, and varying paths to encourage activity for the residents and visitors, which supported the AHTA's recommendations. Garden benches are also provided under shade for relaxing. The gazebo also has seating where residents can enjoy the still water of the pond, which is strategically located

at the lowest elevation of the site where it can double as a stormwater collection element. Spaces, such as the pergola, are also provided for outdoor group activities like yoga or occupational therapy sessions.

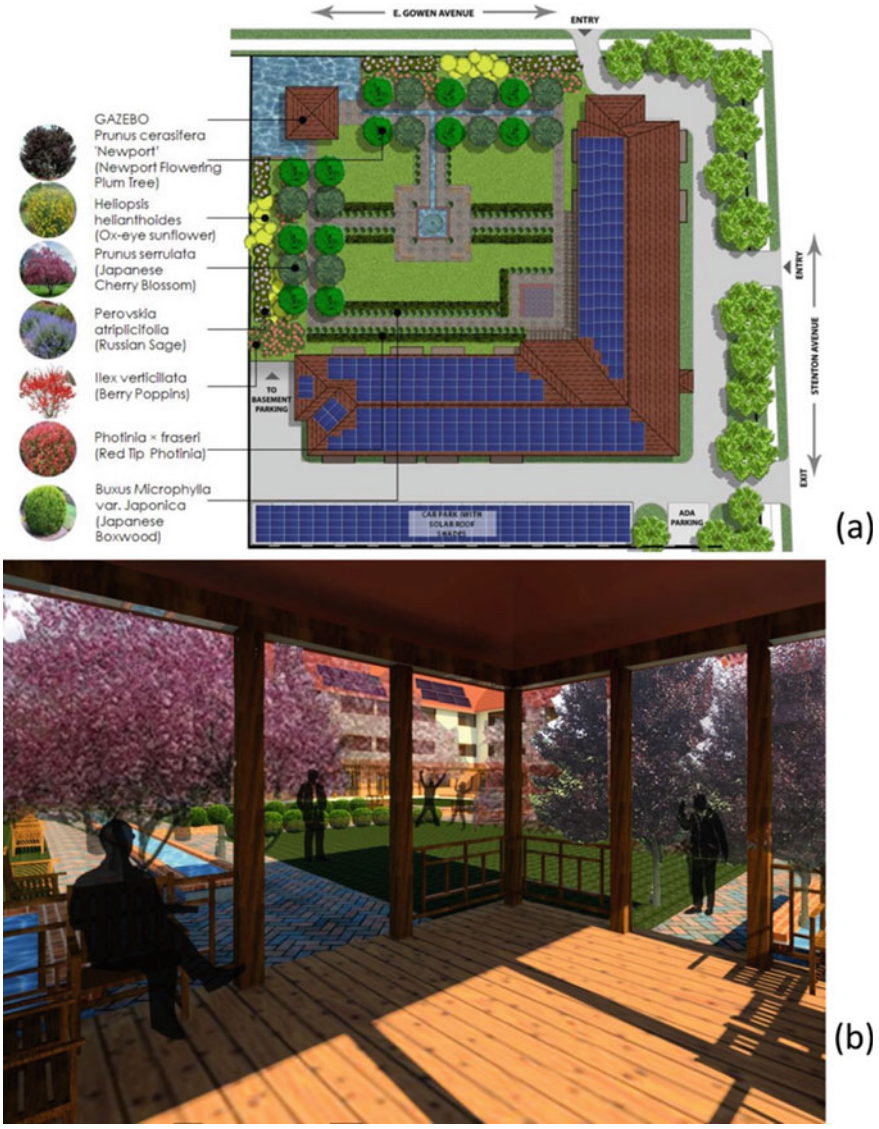

Fig. 10 The proposed site plan redesign, including the new outdoor social spaces and natural vegetation species. The design proposal was informed by the work of Gertrude Jekyll and the AHTA's therapeutic garden recommendations. **a** Shows the site plan and native species; **b** shows a perspective from the pavilion looking towards the building

These outdoor spaces not only help against the coronavirus and social isolation, but they also help provide the needed lux levels of natural daylight to support natural biorhythms. Furthermore, these spaces add needed ecosystems services by the provision of biodiversity to an urban setting which has multiple benefits: reduce the Urban Heat Island Effect, attract declining birds and bees, and remove some pollutants from the local air.

In addition to outdoor spaces, several research projects explored the development of indoor spaces as biophilic gathering rooms. These designs sought to bring the outdoors in by providing views to outside, but also by deploying facsimiles of nature. Among the 14 Patterns of Biophilic Design are Natural Analogues, such as biomorphic forms and patterns, material connection with nature, and complexity and order. These translated into features such as the use of wood, stone on floors and walls; the use of color pallets that are found in nature, including greens, blues, and browns; organic shapes of indoor gardens and the use of indoor vegetation; and lighting that uses organic forms and LED technology that can illuminate sky formations complete with changing light levels and sky colors that match what's happening outdoors throughout the day (Fig. 11).

3 Conclusion

The innovative design approach used in the studios led to more comprehensive design solutions, including proposals that lie beyond the scope of the traditional design education and profession. The students were able to connect dots for themselves through a process of conceptual scaffolding that encouraged them to connect dots between pieces of research, to discover insights that lead them to conclusions, and to ultimately argue for and propose alternatives to the norm based on informed research. They ultimately concluded that architects and professionals have an ethical obligation to do more for seniors and the environment. It is precisely this kind of approach that design education requires to develop leaders of tomorrow. The following conclusions are distilled from the student research.

3.1 Student Conclusions

The design investigations attempted to answer the stated research questions, and were able to define some spatial configurations that could alleviate senior health concerns, but they were also able to speak to the potential for design to engender well-being, and envision senior care centers as life-supporting homes, rather than institutions for the end of life. Below are potential generalized solutions to be adopted in academic studios that are supported from the investigations.

At the individual scale, the notion of resilience is personal as it relates to an individual's physical and psychological states. Supporting mental, physical and