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Design Thinking Applied to Home Textiles Innovation: A Case Study in an Elderly Centre in Hong Kong

Meiyu Yao and Li Li *

Institute of Textiles and Clothing, The Hong Kong Polytechnic University, Hong Kong, China; aliceyao.yao@polyu.edu.hk
* Correspondence: li.lilly@polyu.edu.hk

Abstract: The ageing society is a challenging social issue, yet it implies a growing demand for elderly goods and services. The current development of elderly textile products, however, appears to neglect everyday use. This paper used a case study to demonstrate the utilization of design thinking, a human-centric methodology, in order to design and develop a creative solution for elderly care in elderly centers, taking into account their needs and preferences with regard to textiles. Starting from empathy, complex problems were identified, and ideas were generated. As a skin-protective home textile, chitosan, a natural antibacterial material, has been suggested for development. By using iterative processes, the spinning problem was tackled; the biological and physical characteristics were studied; design, sizing, patterns and printing were created and refined to fulfill the needs; mass production of bedding, apron and handkerchief were successfully achieved; a pre-posttest trial was conducted to determine the satisfaction level and potential help of the prototypes. The feedback was generally positive and highly satisfied. Hence, this study indicates that the design thinking approach may provide an effective method of understanding empathy and discovering solutions most likely to meet the needs of the users.

Keywords: design thinking; service design; home textiles; chitosan; ageing

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1. Introduction

Nowadays, ageing is a worldwide concern. According to World Population Prospects [1,2], approximately 22% of the world's population (about 2.1 billion) will be senior citizens aged over 60 by 2050. Among them, almost 9% (about 426 million) are even aged over 80. Specific to Hong Kong, the number of elderly populations will reach 2.58 million (38.4% of the total population) by 2069 [3]. This implies social challenges but also a growing demand for elderly goods and services. Previous research has indicated that senior citizens have specific needs regarding clothes and textiles [4–6]. The current focus on the development of novel eldercare textile goods centers on smart monitoring, which includes health indicator supervision, falling alert and location monitoring [7–11], protective equipment to lessen the impact pressure of falls [12,13], thermal heating textiles [14], and so on. Although there are existing studies on elderly products that have made good attempts to tackle the health problems of the elderly, there is little uptake among this population due to a lack of acceptance of new innovations, due to either low compatibility, no perceived value, low self-image, different cultural values, potential risks and so on [15]. Scientific research in bedding textiles in particular has been limited in recent years, with only minor changes in performance [4,16]. Hence, this study aims to use design thinking, a human-centric method, to design and develop a creative solution for elderly care with great consideration to their needs and preferences on textiles.

2. Methodology of Design Thinking

In recent decades, researchers and designers have used various methods to tackle problems and develop technology accordingly [17]. Traditionally problem-solving design

research is tactical in nature to provide a suitable solution to a targeted problem [18]. Creative and systematic work has been undertaken to increase knowledge and produce products. Nevertheless, this has only resulted in limited value creation. Doubtlessly, the world will continue to undergo rapid discontinuous changes and become highly interconnected and complicated. Furthermore, previous research has revealed that the world is experiencing critical problems [19,20]. Often, problems are poorly formulated, information is unclear, decision makers hold conflicting values, and the overall implications are vague [21]. Moreover, there has also been a shift from product manufacturing to service experience in economies. The design research method should be strategic and able to bring dramatic new forms of values [18]. Hence, design thinking that utilizes designers' sensibility, professional practice and theoretical reflections beyond the design context is adopted. That means it comprises various tools and frameworks, even drawn from other disciplines, where the driving concern is human-centered experience [22]. Many different fields, including the sciences and business, have adopted this concept for resolving disciplinary problems in innovative ways [23]. The methodology is a creative discovery process. It involves an iterative cycle of five steps: empathic understanding, problem defining, ideation, creation of prototype, and test and evaluation, which are illustrated below [18,24–26].

2.1. Empathic Understanding

Rather than a one-shot vaccine to a specific problem, the design should be a long-term and sustainable change for betterment. The first design thinking process thus requires putting yourself in others' shoes to understand their true feelings and experience. Designers can empathize with users' situations and help relieve them in some way. Hence, this step refers to being human-oriented, empathetic and optimistic about conceiving and exploring the early design process regarding feasibility, viability and desirability. Generally, user experience and motivations can be investigated in multiple ways, including but not limited to observations, interviews, surveys and experiences. One useful method for reflecting problems and experiences is to reflect on it in the manner closest to daily life [27]. Hence, the naturalistic observation of observing and recording users' feelings and experiences outside the laboratory should be adopted for human-centric research. The emphasis should always be placed on the users so each iteration is examined continuously from their perspective, with questions and observations designed to improve upon the solution and gather more information about the needs of the person or people [28]. Sometimes, users may not be clear about the problem or may not be able to explain it, especially the underlying or interrelated problem. Designers need to observe how users use them, why they do it, and why they express it this way. By observing their behavior, body language and emotional expressions, their true experience and feelings can be found. In this case, the current state of the ageing population was analyzed, the needs of senior citizens and their caregivers examined, and the related textile market studied to gain an empathic understanding of the whole picture.

2.2. Problem Defining

Problem definition involves defining the core problem by integrating the information that was created or gathered during the empathic understanding stage. Rather than focusing on the company's need or personal desire, the problem should be described as a practical objective from a human perspective. For example, a restaurant needs to boost its profit, but its current issue is a lack of customers. Nevertheless, in order to apply design thinking, the problem and goal should be defined in an empathic manner. Observation and surveying show that the core problem is due to poor service quality. Hence, instead of "increasing profit by 10%", the problem statement should be "customers demand better service quality to have a better dining experience". That means the problem defining phrase integrates the information gathered and generates ideas for the creation of features, functions, and elements of a product, service or experience that can eventually help to solve the underlying problem with minimal difficulty. In this case, the problem statement

should be more specific to "elderly people need functional textiles for daily use, while their caregivers should be provided with convenience for quality of life improvement". This is discussed in further detail in the next section.

2.3. Ideation

Idea generation is a process by which alternative solutions can be generated by "thinking outside the box". Ideas should be stimulated through brainstorming or other methods as much as possible at the beginning of this stage. The perspective should also be interdisciplinary. Due to the complexity and innovation of interdisciplinary research, designers are able to combine the viewpoints of two or more fields to solve a problem. Especially, since designers are usually confronted with open and challenging problems, their design practices can be learned and adopted [29]. Even through failures or mistakes might be encountered, more failures mean more possibilities to identify and correct incorrect assumptions, discuss, and exchange knowledge, leading to quicker improvements in prototype efficiency [30]. In the process of constantly introducing new ideas and abandoning unfeasible solutions, it realizes the development of novel solutions that are more effective, efficient, and sustainable, while still beneficial to different parties. In this case, an innovative textile material, chitosan textile, was created as a result of idea generation for solving the problem.

2.4. Creation of Prototype

The purpose of prototype development is not only to facilitate the visualization of the solutions generated, but also to facilitate communication within the design team or potential users. It involves investigating the possibility of various solutions and determining the most suitable one. Typically, a small group of individuals outside the design team would be invited to test the prototype and give feedback. As a result of their feedback and experience, the prototype might be accepted, improved, re-developed or rejected. Hence, this stage helps to improve the understanding of the inherent constraints and problems inherent in the solutions. Furthermore, it provides further insights into users' behavior, thinking and emotions when interacting with the terminal. In this case, prototypes were made and refined based on designing, sizing and feedback from the elderly center staff.

2.5. Test and Evaluation

In contrast to the prototype stage, the developed solution would be tested with the potential users. By simulating the actual use conditions, users can provide feedback regarding the applicability and feasibility of the solutions. At this stage, improvements and changes are made to troubleshoot problem solutions. Furthermore, as much insight as possible should be gained concerning the product and its users and further modifications should be made as needed. In this case, biological and objective textile testing was conducted to ensure the suitability and functionality of the product for daily use. Then, 100 sets of prototypes were manufactured and put to the test to determine customer satisfaction.

Any stage in the process can be reversed to re-define the idea and direction for development. A variety of activities seem chaotic yet are orchestrated to achieve innovation and contribute to human well-being. This paper is thus divided into two major parts in order to facilitate understanding. It begins with a discovery process through a human-centric method to discover a creative solution for elderly care in elderly centers (inspiration) and then proceeds to an iterative process of prototyping, testing and refinement (implementation).

3. Part I: From Empathy to Ideation

As previously mentioned, there is an increasing population of senior citizens, which has led to an increase in the demand for related services and goods. In particular, the healthcare sector in Hong Kong is facing dramatic challenges as the growth of caring personnel cannot catch up with the growth of needs. Providing better service and care to elderly people while reducing the burdens on caring personnel has become a difficult chal-

lenge. This project thus cooperated with the elderly center of Tung Wah Group of Hospitals (TWGHs), which has the longest history and is the largest charitable non-governmental organization in Hong Kong devoted to education and community services. In addition to reviewing literature, interviews, site visits and tracking investigations are conducted with sophisticated elderly, caring personnel and experts from other domains, such as textile design and material science, to determine the direction of a solution for alleviating the rapidly raising healthcare needs of the elderly.

The elderly face weakened health conditions and physical dysfunctions, including sensory changes, lowered immune systems, age-related diseases, and bone and muscular frailty [31]. Since the elderly have weakened immune systems, which reduces their body's capacity to fight infection, they are prone to influenza infection and slow wound healing [32]. Some of the elderly may face a weakening function of the urinary bladder, which leads to incontinence [31]. Interviews with elderly individuals revealed that many of them suffered from a certain degree of skin problems, such as eczema, allergies, sores, psoriasis, itching, wounds and so on. Hygiene and friction should, thus, be controlled effectively. Moreover, some elderly may unfortunately lose their mobility and may be confined to their bed most of the time. Additionally, the elderly mentioned that pains caused by their health problems affected their quality of sleep. Quality of sleep, on the other hand, affects the level of recovery and emotional state of the elderly [33]. In order to improve their sleeping quality, the sleeping environment and bedding textiles are important elements [34]. It indicates that elderly centres should not simply offer a thermal condition for sleeping, but also create a home-like environment to provide a comfortable sense of home.

From the point of view of caring personnel, family members are typically the ones who take care for the elderly. Nevertheless, they may not possess the necessary skills or training for the healthcare procedure [32]. Even in elderly centers, caring personnel may have to take care of numerous of elderly people while performing daily work at the same time. When tracking the daily duties of the caring personnel at TWGHs, one of the most time consuming but crucial tasks is cleaning up. In addition, the elderly are expected to change and wash their bedding daily, clean their table, utensils, clothing and other items following meals to ensure hygiene.

As mentioned previously, the elderly have increasing and specific needs for clothing and textiles. During the site visit to the TWGHs, it became apparent that a large amount of textile products would be required for the elderly center. Among the commonly used textile products are bedding, handkerchiefs, aprons, uniforms, carpets, curtains and tablecloths. Despite the fact that daily laundering and sterilization is carried out, their consumption is very high in order to maintain hygiene. It should be noted that caring personnel are also users of these products. The requirements of different users vary. Taking bedding as an example, the elderly are the direct users of them, while caring personnel need to do the cleaning and make the bed. Hence, the level of convenience in cleaning and exchanging is also of great importance. The "solution" should be to satisfy both requirements.

European Project Textiles for an Ageing Society (TAGS) found that the textile products for elderly should consider the following requirements, which align with the observations and interviews results: (1) appearance; (2) climate control; (3) surface properties; and (4) hygiene and maintenance [4,35,36]. Currently, eldercare product research focuses on wearable electronics and smart textiles, especially those with monitoring capabilities or thermal protective functions [8]. With regard to antibacterial or skin care textiles, previous research has focused on medical garments (for treatment or for special purposes) rather than everyday clothing or textiles [37]. Therefore, with regard to the problem and requirements defined, home caring textiles that can provide better health and sanitary care for the elderly whilst alleviating the burden on the healthcare personnel are preferred. It should not simply be a "product" for the elderly, but also a "solution" for them, as well as the caring personnel.

Concerning the current development of technology and textile innovations, although there has been good attempts to develop smart healthcare textiles, those products cannot be

treated the same as normal textile manufacturing and cannot be worn the same as normal apparel. It has been suggested that advancements in the textile technology should consider wearability and the comfort of the wearer during their development [38]. In addition, a bridge should be built between academic research and the commercialization of these products [38,39]. A new direction for textile development in healthcare is needed and these products should be able to support daily usage. This, in turn, creates a reason for elderly and caring personnel to choose these products.

The study of different materials has been conducted through research from literature to comprehend their properties and functionality [40–42]. It has been found that textile materials with antibacterial and wound healing properties can be helpful for providing comfort and healing. Chitosan, mainly derived from shells of crustaceans, exoskeletons of insects and fungal mycelia, is a mucopolysaccharide composed of glucosamine and N-acetylglucosamine [43]. It has gained commercial interest due to its biocompatible, biodegradable, non-toxicity, excellent absorption properties, etc. Therefore, Chitin and chitosan have been widely applied in various aspects, such as photography, cosmetics, medical dressings, artificial skin, ophthalmology, water engineering and so on [44]. Concerning medical application, there are dressing products found on the market made from chitin, such as Beschitin of Unitika. Chitosan can help to control water evaporation, ensure air permeability, promote fluid drainage and inhibit microorganism activities [45,46]. It was also found in a study by Azad et al. that chitosan can help reduce pain and re-epithelialization [47]. Hence, this study proposed the use of this medical material as a daily textile to provide a creative solution to daily caring at elderly centers.

4. Part II: Prototyping, Testing and Refinement

In order to develop the idea into a practical solution for elderly centers, prototyping, testing and refinement processes are iterative in nature and included each fabrication steps of the home caring textiles. The product must meet the daily requirements, including a high level of comfort and convenience, to improve acceptance as a highly human-centric product. The process thus started with material development (fiber and yarn spinning) and functional testing (bio-functions and textile optimization). Then, the ratio of Chitosan fibers to other natural fibers was investigated to determine how best to balance functionality and cost associated with using Chitosan fibers. Additionally, textiles were objectively tested in order to determine their comfort level and suitability for everyday use. Thereafter, the product was sized, designed, and prototyped to suit the preferences and needs of the elderly and caregivers. A wear trial was also conducted in order to assess the level of satisfaction.

First of all, the studies included an investigation of the bio-functions and textile optimization of chitosan fiber and the creation of protective garments with medical functions was carried out. Regarding the optimization of chitosan fabrication, an effective and efficient spinning method to reduce the electrostatic interaction between fibers or between fibers and the spinning rolls was developed [30,48]. This helped to improve the structure, capacity, layering system and material combination of chitosan yarn fabrication and enable future mass production. In addition, most research on chitosan has focused on its soluble form, chemical treatment, and coating methods. There have been relatively few studies involving chitosan in the form of fiber, in particular high-content chitosan-blend yarn or fabrics. The study investigated the solid form of chitosan fiber, which is a textile-based material, and blending was utilized rather than coating to ensure the durability of the material functions [48]. Therefore, biological tests were utilized to evaluate the bio-functions, antimicrobial properties and wound healing abilities of the chitosan textiles. Chitosan textile in its original form considerably improves the proliferation of fibroblast cells [49–54]. For the wound healing test, healthy inbred albino Wistar strain 5-week male rats were used for the study and chitosan textile reduced the time of the first stage and the total time of wound healing by 2–3 days out of 13 days, as shown in Figure 1. Regarding the antimicrobial property of chitosan according to AATCC100, three representative microorganism species of *Stapphylococcus aureus*, *Escherichia coli* and *Canidia albicans* were tested

against fiber samples with a dynamic contact method and contact time of 18 h. Chitosan fiber showed excellent inhibition effects over three microorganism species (killing rate: *Stapphylococcus aureus* 98.1%, *Escherichia coli* 94.1% and *Canidia albicans* 77.6%; Inhibition rates: all over 99%).

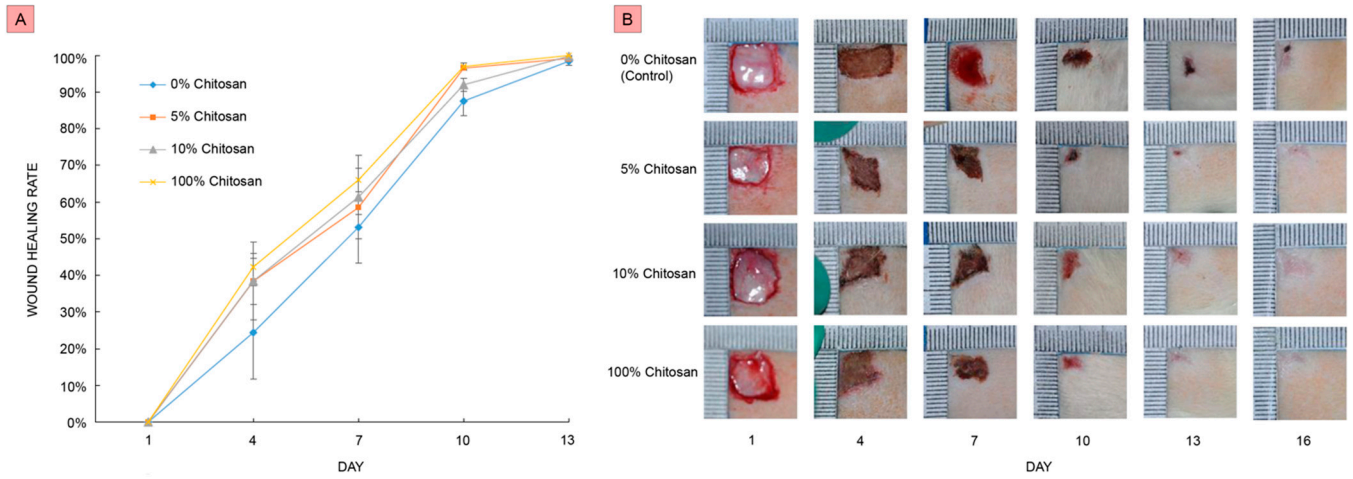

Figure 1. (**A**) Results of wound healing animal test displaying wound healing rates; (**B**) Photos of wounds in the wound healing test.

For the prototype caring products, yarn and fabric consisting of 15% chitosan and 85% cotton were used, since 5–10% chitosan content showed a very high antimicrobial and wound healing effect. Additional antibacterial tests were conducted. The results showed a 70% reduction in *escherichia coli* after 1 h of contact (ASTM E 2149-13A); a 74% inhibition of *staphylococcus aureus* growth after 18 h of contact (GB/T 20944.3-2008) and an 85% inhibition of *Candida albicans* growth after 18 h of contact GB/T 20944.3-2008). In addition to the biological testing, the samples produced were subjected to a number of objective tests to ensure their daily performance before mass production. The physical properties of the samples were examined using international standards, and detailed results are presented on Table 1. The tested textile passed all the requirements necessary for daily usage, such as yarn count, tenacity, evenness, hairiness, and color fastness.

Table 1. Physical test results.

	Testing Standards	Requirements	Test Results
Yarn Count		>10 Ne	19.75 Ne
Tenacity		>12.0 cN/tex	21.55 cN/tex
Evenness		<20%	15.7%
Hairiness		<5.5	5.38
Fabric Touch Tester (FTT test)		Softness > 0.4	Face: 0.42/Back: 0.42
		Stiffness > 0.4	Face: 0.47/Back: 0.71
Pilling Resistance	ISO12945-1:2000	3	3–4
Colour Fastness to Water	GB/T5713-2013	4	4
Colour Fastness to Perspiration	GB/T3922-2013	Alkali Resistance: 4	4
		Acid Resistance: 4	4
Colour Fastness to Rubbing	GB/T3920-2008	Dry Friction Resistance: 4	4–5
Formaldehyde	GB/T2912.1-2009		0 (Formaldehyde Free)
pH of aqueous extract	GB/T7573-2009		7.6 (Neutral)
Waterproof	AATCC 35-2000		Pass

For the purposes of ensuring a high level of comfort, the softness and stiffness tests were carried out according to the Fabric Touch Tester (FTT test) standard. The tests simulated four kinds of touching gestures with five parameters tested; they were roughness,

friction, bending, compression and flux. They were associated with the subjective sensation of stiffness, softness and warmth. The final scores were over 0.4, which passed the standard. The samples were formaldehyde free with a neutral pH value which was suitable for daily usage. In addition, a water-proof test was carried out for developing a water-proof pad. In order to find out the daily washing condition, washing-circles were performed 20 times in the condition of 75 °C washing and 90 °C oven-dry. SEM inspections were carried out every 5 times of washing and water resistance tests were conducted. The results can be found in Figure 2.

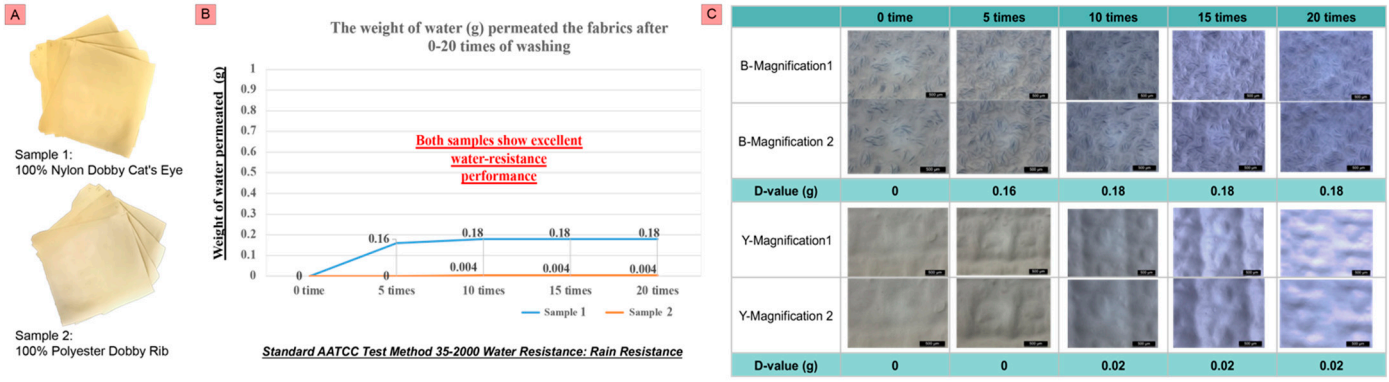

Figure 2. (**A**) Samples for waterproof pad; (**B**) The results of water-proof test; (**C**) SEM images of different washing circles.

Upon discussion with TWGHs and their request, this project produced a total of 100 sets of prototypes, including 200 pieces of handkerchiefs, 200 pieces of aprons (drool bib), and 100 sets of four-piece beddings (pillowcase, bed sheet, quilt cover and waterproof pad) for the daily trial. As mentioned, the prototypes were made with 15% chitosan and 85% cotton to balance both functional and comfort requirements. Beddings, aprons, and handkerchiefs are frequently touched and easily breed bacteria. Thus, the anti-bacterial function is hoped to alleviate the immediate cleaning burden on healthcare personnel and provide skin-protective home-care textiles for daily usage by the elderly. Moreover, bedding are essential products for everyone, especially for those elderly who are confined to their bed most of the time. Additionally, it was mentioned that older persons may experience weakening of the urinary bladder, resulting in incontinence. Sometimes cleaning does not take place immediately after incontinence, making antibacterial bedding appealing. It is also the reason why a waterproof pad is included with the bedding set. Handkerchiefs and aprons are the most frequently used hygiene products used directly on the faces and hands of the elderly. Additionally, the apron was designed to prevent food residue and saliva from getting onto the chest, irritating the skin, and avoid laundering difficulties (often washing with bleach or high temperature could damage the fabric structure and reduce the durability). To ensure the function of waterproofing, an additional layer of fabric consisting of 100% Nylon Dobby Cat's Eye and 100% Polyester Dobby Rib was sewn. For example, the waterproof blanket was constructed using a waterproof fabric as the bottom layer (shown in Figure 3). Regarding the size of the proposed home caring products, measurement was carried out with the help of TWGHs. Some modifications to the size of their current home caring products were conducted according to the opinions of the staff. After a few fittings and modifications, the final sizes and designs are shown in Figure 3.

In addition to sizing and designing, a variety of patterns were used, such as a geometric pattern, a bamboo pattern and a flower pattern, to suit the preference of elderly to give them a feeling of home. Following the collection of ideas and feedback from the elderly and caregivers, the design, patterns, and colors were chosen accordingly. Based on previous research, bright colors are also known to produce predominantly positive emotions [55]. This suggests that they may be beneficial to use. Thus, Chinese patterns representing longevity and happiness were primarily used, along with bright colors. A circular screen-

printing machine was employed to enhance the brightness of the colored patterns. Each cylinder represents a specific color. If a pattern requires five colors, five cylinders are required to print the pattern. Consequently, twelve different colors were printed. There were a number of details designed to enable bedding changes to be as comfortable as possible. These are shown in Figure 4.

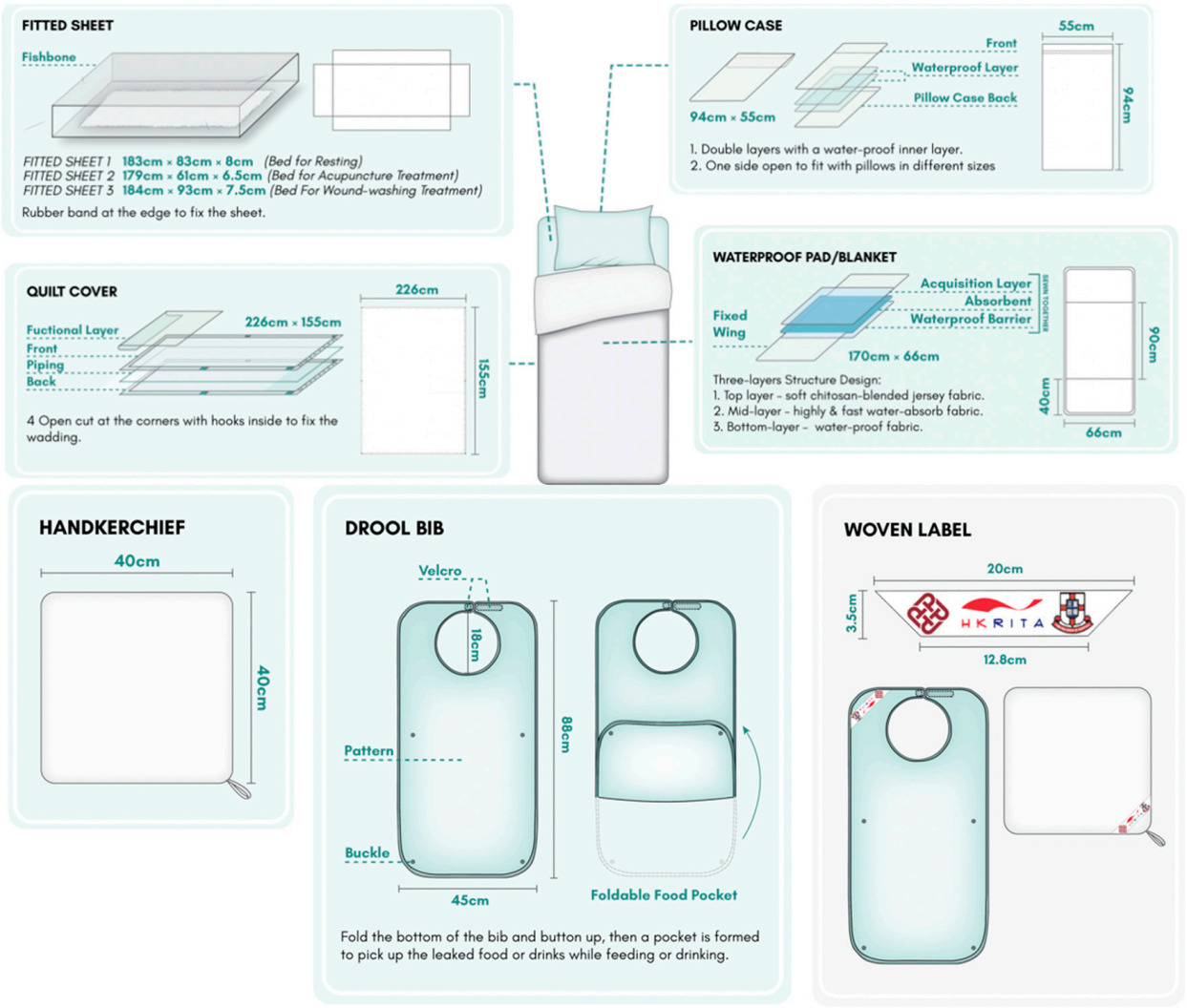

Figure 3. Basic design and sizing of the prototypes.

The apron is waterproof on the top layer to resist dirt. There are buckles at the bottom part of the apron to form a "pocket" where food residue can be trapped. There is also Velcro at the neckline for adjusting the size. The final pattern design had bright colors and an interesting pattern to make it more attractive and to produce predominantly positive emotions [55]. Sample patterns are shown in Figure 4. A repeated washing testing was performed again to ensure the color fastness of the waterproof fabric would meet daily usage requirements. After the 30-times water test, the colors remained stable and apparent, and they did not change significantly from the result of the first test.

The trial was then carried out to collect feedback and evaluation in terms of the comfort and function performance. An analysis of the results of the wear trial can further improve the production manual development for industrial promotion. The wear trial was conducted at three centers of TWGH Centers. Using convenience sampling, the elderly of the facilities was asked if they would be willing to participate. The exclusion criteria for subjects were elderly individuals with dementia whose declining cognitive and intellectual

function may impair their ability to respond. The testing products were bedding, aprons and handkerchiefs. Pre-posttest quantitative survey, causal conversation and observation were adopted. For the pre-test, the elderly from the centers were invited for the trial. In order to ensure the safety of the subjects, the wear trials were closely monitored by researchers and care personnel. Elderly participants were informed about the procedures, potential benefits, and risks associated with the study. They were made aware that the trial is voluntary in nature, and they could stop at any time if they did not feel well. An information sheet was also distributed to them and their guardians, if any. They and their guardian, if any, were also required to sign a consent form before the trials. All the procedures were approved by the university's Human Research Ethics Committee. A pre-test questionnaire was also completed. Except for basic information, such as skin status, all questions were Likert scale questions which contained 7-points (1 as the lowest and 7 as the highest). During the trial, bedding, aprons and handkerchiefs were used by the elderly and washed following usual practice. Observations were conducted to monitor the procedure and ensure the safety. The participants used the products at comfort and in the usual environment of the elderly centers for six weeks. For the post-test, the elderly completed a post-test questionnaire to find out other satisfaction levels regarding the proposed products. For administering the questionnaire, care personnel, who are usually responsible for taking care of the participants, were instructed in the details of the questionnaire, and then they helped the elderly participants in administering the questionnaire if they felt it was more comfortable for them. Therefore, researchers or care personnel read each question to the elderly and ensured that they understood it. Medical personnel were also invited for a simple conversation section in order to obtain further insights. Data were analyzed as below, and feedbacks were given to TWGHs for their future consideration on textile products usage.

Figure 4. (**A**) The demonstration design of the handkerchief, bedding and apron; (**B**) cylinders for circular screen-printing; (**C**) detailed design elements; (**D**) fitting of bedding and the related design elements.

The number of distributed questionnaires was 196, while the received effective questionnaire was 188. The number of used caring products were 67 for aprons, 54 for bedding and 67 for handkerchiefs. The average age was 82.4. The satisfaction level and paired *t*-test results showed a statistically significant increase in average satisfaction level on all factors, which means participants seemed to be more satisfied with the newly developed chitosan caring products. The results are shown in Table 2. Taking "easiness for cleaning" as an example. Participants' satisfaction level was higher after using the chitosan caring products for 6 weeks (5.02 ± 1.03) than using conventional caring products (4.44 ± 1.34);

a statistically significant mean increase of 0.585 (95% Confidence Interval, 0.281 to 0.889), t = 3.80, $p < 0.000$.

Table 2. Satisfaction level and *t*-test result of the trial.

	Pre-Test		Post-Test						
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**	**Difference**	**95% Confidence Interval**		**T-Value**	***p*-Value**
Easiness for Clean	4.44	1.34	5.02	1.03	0.585	0.281	0.889	3.80	0.000
Comfort of Products	4.57	1.27	5.34	0.95	0.766	0.482	1.050	5.32	0.000
Style of Products	4.12	1.15	5.20	1.02	1.080	0.813	1.346	7.99	0.000
Size of Products	4.12	1.13	5.05	1.11	0.931	0.650	1.211	6.55	0.000
Convenience	4.35	1.13	5.13	1.17	0.782	0.502	1.062	5.51	0.000
Function of Products	4.11	1.09	5.15	0.95	1.043	0.794	1.291	8.26	0.000

Additionally, a relative importance and satisfaction level matrix [56] was presented for finding out the future focus for further improvement. The mean of importance (4.370) was the mean of importance score for all factors, while the mean of satisfaction (5.148) was the mean of satisfaction score of all factors. Mean was used as the indicators as all factors were rated as "highly satisfied" by participants already (over 4). It helped find out the relatively weak areas for further improvement. Table 3 shows the mean value of importance and satisfaction level rated by participants and Figure 5 shows the matrix. "Convenience" and "Easiness for cleaning" should be improved, as they had relative high importance yet relative low satisfaction.

Table 3. Relative importance and satisfaction level.

	Satisfaction	**Importance**
Easiness for Clean	5.02	4.60
Comfort of Products	5.34	4.70
Style of Products	5.20	4.02
Size of Products	5.05	4.13
Convenience	5.13	4.42
Function of Products	5.15	4.36
Mean	5.148	4.370

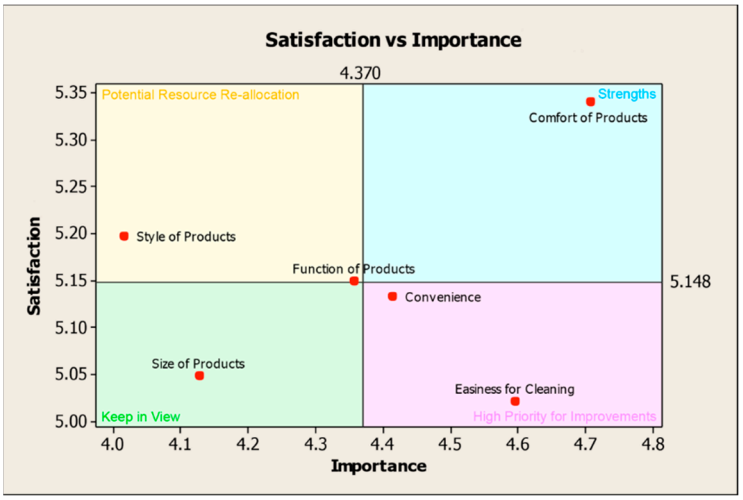

Figure 5. Matrix showing the relative importance and satisfaction level.

The skin status rating, agreement with the statement "my health status is very good" and satisfaction with life scale (developed by Diener et al. [57]) all showed positive results after using the developed caring products. The number of people who rated their skin status as "healthy" was 139 for the pre-test and 164 for post-test. For the statement, participants felt healthier after using the chitosan products. The paired *t*-test showed significant differences: an increase of 0.505 (95% Confidence Interval, 0.306 to 0.705), t = 5.00, $p < 0.000$. For the satisfaction with life scale, a total score of 21–25 means slightly satisfied with life. Participants had a higher score after using the chitosan caring products. The paired *t*-test showed significant a difference with an increase of 2.947 (95% Confidence Interval, 2.118 to 3.776), t = 7.01, $p < 0.000$. Details can be found in Table 4. This demonstrated potentially improved skin health and life satisfaction.

Table 4. *t*-test result of the agreement with the statement "my health status is very good" and satisfaction with life scale.

	Pre-Test		Post-Test						
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**	**Difference**	**95% Confidence Interval**		**T-Value**	***p*-Value**
Agreement of statement "My health status is very good."	4.18	1.15	4.68	0.91	0.505	0.306	0.705	5.00	0.000
Satisfaction with Life Scale	21.21	4.25	24.15	4.34	2.947	2.118	3.776	7.01	0.000

For the observation and casual conversation with caring personnel and staff, they generally provided very positive feedback and highly appreciated the caring products produced. They were asked about the insights they gained from using the products via an open question, "What are your thoughts on the products?". According to them, the design of the bedding allowed them to be easily changed, facilitating convenient working. In addition, they found that the apron was relatively easier to clean than previous products, and the waterproofing feature helped reduce dirt accumulation. They were also very satisfied with the fitting and attractive pattern designed. Figure 6 shows the final prototypes and the elderly wearing the apron. They were satisfied and happy with the products.

Figure 6. (**A**) A photo showing the elderly of TWGHs wearing the developed apron; (**B**) Photos showing the final prototypes.

5. Conclusions

In this case study, design thinking was used in place of traditional problem-solving research to address the needs of the elderly innovatively. With design thinking, the focus is on end-users and incremental releases in order to sustain high levels of satisfaction through the continuous delivery of valuable features. Figure 7 illustrates the processes involved. The requirements and needs of different end users were identified by using empathy as a starting point. Using the appropriate care textile products could ease the burden on caregivers significantly, while natural fabrics are better for the skin of the elderly. Additionally, current daily home textiles lack functionality, and advanced technology may not be readily accepted by elderly persons. Thus, this study crossed the boundary between textile products and tried to find a solution from multiple standpoints, such as fashion design, textile technology, material science, biology, and medicine. As studied, chitosan exhibited antibacterial properties, making it suitable for use in hospitals and elderly centers. Therefore, the objective of this project was to develop caring products for the elderly using chitosan and cotton blend yarn and to cooperate with TWGHs in conducting the actual trial. Therefore, the iterative process makes use of chitosan and solves problems related to the production of protective textiles for medical and healthcare purposes. In preparation for the trial, the fabrics were subjected to a variety of objective tests to ensure that their physical properties, comfort level, and antibacterial properties met the standards required for real-world use. The results of all tests demonstrated good quality and met international standards. Later, discussions and site visits were conducted continuously at the elderly centers of TWGHs in order to determine accurate product specifications and to design the highly preferred patterns for elderly people. A total of 100 sets of bedding, an apron, and a handkerchief were produced and sent to TWGHs for testing. A 6-week pre-post trial was conducted. A questionnaire and casual conversation were conducted in order to collect feedback from the elderly and caregivers. The results indicated an increase in satisfaction and a potential improvement in health status.

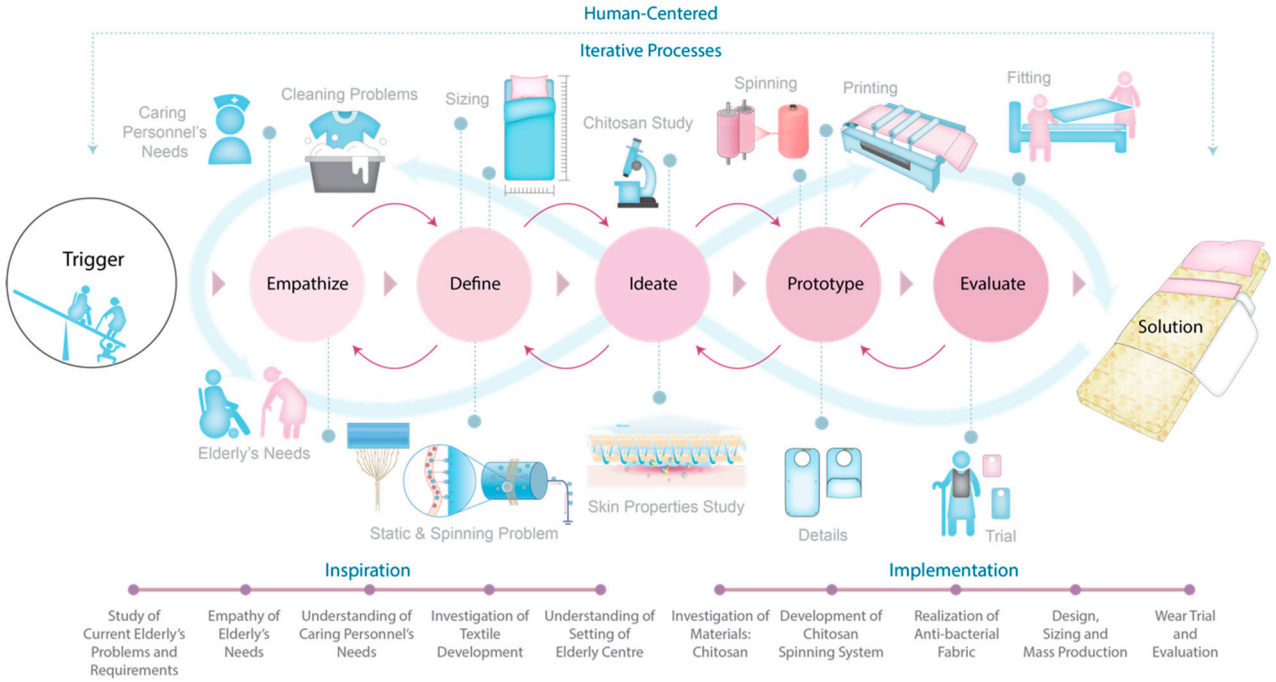

Figure 7. The design thinking processes.

To conclude, the study provides a case study for the application of design thinking to the development of eldercare products. It demonstrates how elderly textile development can be achieved through human-centered research. The development of elderly products utilizing a deep user research method and direct communication with end users can

significantly lower the barriers to product development and maximize the benefits to the end-users. Therefore, this study indicates that the design thinking approach may provide an effective method of understanding empathy and discovering solutions most likely to meet the needs of the users.

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References

1. World Health Organization. Ageing and Health. 4 October 2021. Available online: https://www.who.int/news-room/fact-sheets/detail/ageing-and-health (accessed on 25 April 2022).
2. United Nations. World Population Prospects 2019 Highlights. 2019. Available online: https://population.un.org/wpp/Publications/Files/WPP2019_Highlights.pdf (accessed on 25 April 2022).
3. Hong Kong Census and Statistics Department. Hong Kong Population Projections 2020–2069. 2020. Available online: https://www.statistics.gov.hk/pub/B1120015082020XXXXB0100.pdf (accessed on 25 April 2022).
4. Blaylock, A.; Constantin, F.; Ligabue, L.; Bocaletti, L.; Siroka, B.; Siroky, J.; Wright, T.; Bechtold, T. Caregiver's vision of bedding textiles for elderly. *Fash. Text.* **2015**, *2*, 6. [CrossRef]
5. Twigg, J. Adjusting the cut: Fashion, the body and age on the UK high street. *Ageing Soc.* **2012**, *32*, 1030–1054. [CrossRef]
6. Hurd Clarke, L.; Griffin, M.; Maliha, K. Bat wings, bunions, and turkey wattles: Body transgressions and older women's strategic clothing choices. *Ageing Soc.* **2009**, *29*, 709–726. [CrossRef]
7. Scataglini, S.; Imbesi, S. Human-centered design smart clothing for ambient assisted living of elderly users: Considerations in the COVID-19 pandemic perspective. In *IoT in Healthcare and Ambient Assisted Living*; Springer: Singapore, 2021; pp. 311–324.
8. Bravo, V.P.; Muñoz, J.A. Wearables and their applications for the rehabilitation of elderly people. *Med. Biol. Eng. Comput.* **2022**, *60*, 1239–1252. [CrossRef] [PubMed]
9. Stavropoulos, T.G.; Papastergiou, A.; Mpaltadoros, L.; Nikolopoulos, S.; Kompatsiaris, I. IoT wearable sensors and devices in elderly care: A literature review. *Sensors* **2020**, *20*, 2826. [CrossRef]
10. Wei, W. A summary of the research status and development trends of protective clothing for the elderly. In Journal of Physics: Conference Series; IOP Publishing, Bristol, UK, 2021; Volume 1790, p. 012024. In *Journal of Physics: Conference Series*; IOP Publishing: Bristol, UK, 2021; Volume 1790, p. 012024.
11. Wang, S.; Li, Y.; Chen, X. Study on the Design of Intelligent Positioning Clothing for Preventing the Elderly from Getting Lost. In *Journal of Physics: Conference Series*; IOP Publishing: Bristol, UK, 2021; Volume 1790, p. 012049.
12. Wardiningsih, W.; Troynikov, O. Treated knitted fabric for hip-protective pads for elderly women, part I: Force attenuation capacity. *Text. Res. J.* **2019**, *89*, 1408–1416. [CrossRef]
13. Wardiningsih, W.; Troynikov, O. Treated knitted fabric for hip protective pads for elderly women. Part II. Performance relevant to thermal comfort. *Text. Res. J.* **2019**, *89*, 5006–5013. [CrossRef]
14. Stygienė, L.; Varnaitė-Žuravliova, S.; Abraitienė, A.; Padleckienė, I.; Krauledas, S. Investigation of textile heating element in simulated wearing conditions. *Autex Res. J.* **2021**, *21*, 207–215. [CrossRef]
15. Lunsford, D.A.; Burnett, M.S. Marketing product innovations to the elderly: Understanding the barriers to adoption. *J. Consum. Mark.* **1992**, *9*, 53–62. [CrossRef]
16. Meinander, H.; Varheenmaa, M. Clothing and Textiles for Disabled and Elderly People; VTT Tiedotteita. 2002. Available online: https://www.vttresearch.com/sites/default/files/pdf/tiedotteet/2002/T2143.pdf (accessed on 25 April 2022).

17. Deek, F.P.; Turoff, M.; McHugh, J.A. A common model for problem solving and program development. *IEEE Trans. Educ.* **1999**, *42*, 331–336. [CrossRef]
18. Brown, T. *Design Thinking*; Harvard Business Review: Brighton, MA, USA, 2008; p. 1.
19. Pusca, D.; Northwood, D.O. Design thinking and its application to problem solving. *Glob. J. Eng. Educ.* **2018**, *20*, 3.
20. Rittel, H.W. *The Reasoning of Designers*; IGP: Boston, MA, USA, 1988; p. 12.
21. Buchanan, R. Wicked problems in design thinking. *Des. Issues* **1992**, *8*, 5–21. [CrossRef]
22. Gobble, M.M. Design thinking. *Res.-Technol. Manag.* **2014**, *57*, 59–62.
23. Kimbell, L. Rethinking design thinking: Part I. *Des. Cult.* **2011**, *3*, 285–306. [CrossRef]
24. Brown, T.; Katz, B. *Change by Design: How Design Thinking Transforms Organizations and Inspires Innovation*; HarperBusiness: New York, NY, USA, 2019; Volume 20091.
25. Dam, R.F.; Siang, T.Y. *Design Thinking: A Quick Overview*; Interaction Design Foundation: Aarhus, Denmark, 2020.
26. Wolniak, R. The Design Thinking method and its stages. *Syst. Wspomagania Inżynierii Prod.* **2017**, *6*, 247–255.
27. Skaggs, P. Design thinking: Empathy through observation, experience, and inquiry. In Proceedings of the Society for Information Technology & Teacher Education International Conference, Washington, DC, USA, 26–30 March 2018; Association for the Advancement of Computing in Education (AACE): Washington, DC, USA, 2018; pp. 1168–1172.
28. Darbellay, F.; Moody, Z.; Lubart, T. (Eds.) *Creativity, Design Thinking and Interdisciplinarity*; Springer: Singapore, 2017.
29. Bjögvinsson, E.; Ehn, P.; Hillgren, P.A. Design things and design thinking: Contemporary participatory design challenges. *Des. Issues* **2012**, *28*, 101–116. [CrossRef]
30. Guo, H.F.; Lam, N.Y.; Yang, C.X.; Li, L. Simulating three-dimensional dynamics of flexible fibers in a ring spinning triangle: Chitosan and cotton fibers. *Text. Res. J.* **2016**, *87*, 1403–1410. [CrossRef]
31. Jaul, E.; Barron, J. Age-related diseases and clinical and public health implications for the 85 years old and over population. *Front. Public Health* **2017**, *5*, 335. [CrossRef]
32. Gould, L.; Abadir, P.; Brem, H.; Carter, M.; Conner-Kerr, T.; Davidson, J.; DiPietro, L.; Falanga, V.; Fife, C.; Grice, E.; et al. Chronic wound repair and healing in older adults: Current status and future research. *Wound Repair Regen.* **2015**, *23*, 1–13. [CrossRef]
33. Van Someren, E.J.W. Circadian and sleep disturbances in the elderly. *Exp. Gerontol.* **2000**, *35*, 1229–1237. [CrossRef]
34. Zbikowski, P.; Loker, S. Clothing and bedding practices and hypothermia awareness of elders: A comparative study. *Cloth. Text. Res. J.* **1992**, *10*, 30–34. [CrossRef]
35. Gerhardt, L.C.; Lenz, A.; Spencer, N.D.; Münzer, T.; Derler, S. Skin–textile friction and skin elasticity in young and aged persons. *Ski. Res. Technol.* **2009**, *15*, 288–298. [CrossRef] [PubMed]
36. Bloomfield, S.F.; Exner, M.; Signorelli, C.; Nath, K.J.; Scott, E.A. The infection risks associated with clothing and household linens in home and everyday life settings, and the role of laundry. In *International Scientific Forum on Home Hygiene*; UK, 2011. Available online: https://europeantissue.com/wp-content/uploads/The-infection-risks-associated-with-clothing-and-household-linens.pdf (accessed on 25 April 2022).
37. Sau-Fun, N.; Chi-Leung, H.; Lai-Fan, W. Development of medical garments and apparel for the elderly and the disabled. *Text. Prog.* **2011**, *43*, 235–285. [CrossRef]
38. Choudhry, N.A.; Arnold, L.; Rasheed, A.; Khan, I.A.; Wang, L. Textronics—A Review of Textile-Based Wearable Electronics. *Adv. Eng. Mater.* **2021**, *23*, 2100469. [CrossRef]
39. Libanori, A.; Chen, G.; Zhao, X.; Zhou, Y.; Chen, J. Smart textiles for personalized healthcare. *Nat. Electron.* **2022**, *5*, 142–156. [CrossRef]
40. Andra, S.; Jeevanandam, J.; Muthalagu, M. Emerging nanomaterials for antibacterial textile fabrication. *Naunyn-Schmiedeberg's Arch. Pharmacol.* **2021**, *394*, 1355–1382. [CrossRef]
41. Butola, B.S. Recent advances in chitosan polysaccharide and its derivatives in antimicrobial modification of textile materials. *Int. J. Biol. Macromol.* **2019**, *121*, 905–912.
42. Shahidi, S.; Wiener, J. Antibacterial agents in textile industry. *Antimicrob. Agents* **2012**, 387–406. [CrossRef]
43. Zikakis, J. (Ed.) *Chitin, Chitosan, and Related Enzymes*; Elsevier: Amsterdam, The Netherlands, 2012.
44. Kumar, M.N.R. A review of chitin and chitosan applications. *React. Funct. Polym.* **2000**, *46*, 1–27. [CrossRef]
45. Mi, F.L.; Shyu, S.S.; Wu, Y.B.; Lee, S.T.; Shyong, J.Y.; Huang, R.N. Fabrication and characterization of a sponge-like asymmetric chitosan membrane as a wound dressing. *Biomaterials* **2001**, *22*, 165–173. [CrossRef]
46. Lou, C.W. Process technology and properties evaluation of a chitosan-coated Tencel/cotton nonwoven fabric as a wound dressing. *Fibers Polym.* **2008**, *9*, 286–292. [CrossRef]
47. Azad, A.K.; Sermsintham, N.; Chandrkrachang, S.; Stevens, W.F. Chitosan membrane as a wound-healing dressing: Characterization and clinical application. *J. Biomed. Mater. Res. Part B Appl. Biomater. Off.* **2004**, *69*, 216–222. [CrossRef] [PubMed]
48. Liu, S.; Hua, T.; Luo, X.; Lam, N.Y.; Tao, X.M.; Li, L. A novel approach to improving the quality of chitosan blended yarns using static theory. *Text. Res. J.* **2015**, *85*, 1022–1034. [CrossRef]
49. Luo, X.; Yao, M.Y.; Li, L. Application of chitosan in the form of textile: Production and sourcing. *Text. Res. J.* **2022**. [CrossRef]
50. Luo, X.; Li, L. Evaluation of single-component chitosan fiber: From advanced materials to contemporary fashion manufacturing. *Text. Res. J.* **2019**, *90*, 125–134. [CrossRef]
51. Luo, X.; Li, L. Design of quantification methods for cross-sectional uniformity of functional fiber blended yarns. *Text. Res. J.* **2020**, *90*, 1872–1880. [CrossRef]

52. Lam, N.Y.K.; Zhang, M.; Guo, H.F.; Ho, C.P.; Li, L. Effect of fiber length and blending method on the tensile properties of ring spun chitosan–cotton blend yarns. *Text. Res. J.* **2017**, *87*, 244–257. [CrossRef]
53. Lam, N.Y.K.; Zhang, M.; Yang, C.; Ho, C.P.; Li, L. A pilot intervention with chitosan/cotton knitted jersey fabric to provide comfort for epidermolysis bullosa patients. *Text. Res. J.* **2018**, *88*, 704–716. [CrossRef]
54. Li, L.; Luo, X.; Leung, H.M.; Law, K.W. Controlled release of borneol from nano-fibrous poly(L-lactic acid)/cellulose acetate butyrate membrane. *Text. Res. J.* **2015**, *86*, 1202–1209. [CrossRef]
55. Hemphill, M. A note on adults' color–emotion associations. *J. Genet. Psychol.* **1996**, *157*, 275–280. [CrossRef]
56. Martilla, J.A.; James, J.C. Importance-performance analysis. *J. Mark.* **1977**, *41*, 77–79. [CrossRef]
57. Diener, E.D.; Emmons, R.A.; Larsen, R.J.; Griffin, S. The satisfaction with life scale. *J. Personal. Assess.* **1985**, *49*, 71–75. [CrossRef] [PubMed]