sustainability

MDPI

Article

Research on Bamboo Furniture Design Based on D4S (Design for Sustainability)

Wenxin Deng *, Hong Lin and Mu Jiang *

School of Art, Soochow University, Suzhou 215123, China
* Correspondence: 20224005007@stu.suda.edu.cn (W.D.); jiangmu@suda.edu.cn (M.J.)

Abstract: D4S (design for sustainability) is derived from the concept of "sustainable development". The situation of energy and material resources directly dependent on human beings is deteriorating in the face of the major global problems threatening human development, such as population increase, desertification of the land, climate warming, forest reduction, extinction of species, and energy scarcity. Design plays a very important role in social development. On the one hand, design changes people's lives. On the other hand, ecological damage, waste of resources, and environmental pollution also arise as a result of design activities. In this context, the concept of sustainable design comes into being. Based on D4S theory, this paper discusses the characteristics of bamboo and its application as a sustainable environmental material in furniture design. The status quo and problems of sustainable furniture design are analyzed using the sustainable design method, and the characteristics and processing technology of bamboo are preliminarily discussed, which provide a useful reference for sustainable design research related to bamboo furniture products. Secondly, the sustainable design strategy of bamboo furniture is put forward, sustainable design methods and principles of bamboo furniture are summarized, and sustainable design is explored through the practice of bamboo furniture design. Finally, an inventory of bamboo furniture design stage is compiled, which is scored according to design, plan implementation, and waste disposal to judge whether bamboo furniture meets the goal of sustainable development.

Keywords: D4S; bamboo furniture; innovative design method; design evaluation

Citation: Deng, W.; Lin, H.; Jiang, M. Research on Bamboo Furniture Design Based on D4S (Design for Sustainability). *Sustainability* **2023**, *15*, 8832. https://doi.org/10.3390/su15118832

Academic Editor: Yoshiki Shimomura

Received: 3 January 2023
Revised: 25 May 2023
Accepted: 29 May 2023
Published: 30 May 2023

1. Introduction

In the 21st century, with the rapid development of human society, the demand for resources has far exceeded the earth's supply capacity, causing a huge ecological deficit [1]. Major global problems such as environmental degradation, climate warming, energy shortages, and health security threaten human existence [2]. The exploitation and utilization of renewable energy is an effective way for the sustainable development of society [3]. Bamboo is a sustainable biological resource that can be rapidly regenerated [4]. The existing technology shows that bamboo has a wide application value and has attracted attention from all over the world [5]. Furniture is an important tool in the human living environment, and with the improvement of people's living standards, in addition to meeting people's needs for furniture, it also conforms to the principles of sustainable development [6,7]. Through the exploration of bamboo furniture design, it is possible to improve the status of bamboo furniture design, adapt to the requirements of bamboo furniture sustainable development, and promote the continuous improvement of bamboo furniture and the healthy development of the human habitat, so as to advance harmonious coexistence and sustainable development among people, society, and the environment.

Furniture is necessary for people's daily life. It is of great significance to social development to attach importance to the sustainable development of furniture. At present, furniture design under the concept of sustainable development is more focused on the technical aspects of materials, technology, etc. [8,9]. Bamboo furniture has been popular

since ancient times as it is healthy for the environment and because there are abundant bamboo resources. On the one hand, bamboo furniture itself is considered naturally sustainable and does not require special consideration in design [10]. Therefore, bamboo furniture changes more quickly than other furniture, leading to serious waste when people use bamboo furniture. On the other hand, while the mechanical properties and service life of bamboo planks are somewhat affected, the resource and energy consumption generated by the secondary processing of bamboo planks greatly reduces their sustainability [11]. In addition, current bamboo furniture designs tend to only consider the "creation" aspects of design, such as form and function, while neglecting the "circulation" aspects of packaging, transport, use processes, and product waste, which are often areas of particular concern for sustainable design [12].

Based on sustainable development, D4S utilizes the knowledge and principles of ecological design, green design, and regenerative design, combines the characteristics and attributes of the sustainable design system, explores rational planning and the design of the human–machine environment, and builds a sound sustainable system of overall coordination and harmonious co-existence to provide systematic design services for human life and development [13,14]. The general principles of sustainable product design are integrity, coordination, liquidity, and innovation [15]. Specific principles are shown in Table 1.

Table 1. General principles of sustainable design.

Principles	Specific Instructions
Integral	Starting from the whole, we minimize the consumption and waste in the activities of design, production, sales, and usage to achieve the purpose of protecting energy resources.
Harmony	From the concept of harmony, through optimal design, we create a harmonious relationship between humans, machines, the environment, and society to achieve the purpose of harmonious coexistence.
Circulation	From the purpose of recycling, we can preserve, expand renewable resources and make reasonable use of nonrenewable resources, and extend their service life to achieve recycling through recycling design.
Innovation	From the sustainable design method, the existing product design is going to achieve innovation in terms of function, shape, structure, practicality, and cultural connotation.

This paper studies and analyzes the advantages, disadvantages, opportunities, and threats of bamboo furniture to provide a favorable direction for bamboo furniture development. This can be used to study and formulate relevant domestic and international certifications in order to standardize and promote the domestic bamboo furniture market and environment, and expand domestic and international markets to provide an important basis. Based on the existing theoretical framework of sustainable design research and the characteristics and processing factors of bamboo, this paper proposes the application of a sustainable bamboo design strategy in furniture product design. Through the limitation of the traditional bamboo application range, this paper highlights the wide application of bamboo in furniture product field, presents innovative solution design research and design practice, and finally evaluates whether bamboo furniture products reach the sustainable development goal by scoring the design checklist.

2. Literature Review

2.1. Research on the Concept of Sustainable Design

The concept of sustainable design derives from the concept of sustainable development. In 1980, the International Union for Conservation of Nature (IUCN) and others published the World Conservation Program (WCP), which proposed the slogan and concept of "sustainable development". Subsequently, in 1983, the United Nations established the World Commission on Environment and Development. In its 1987 study "Our common future", the organization defined "sustainable development" for the first time as development that meets the needs of present generations without compromising the ability of future genera-

tions to meet their needs [16–18]. This shows that human society can maintain ecosystems and make rational use of natural resources while achieving economic development and prosperity. The Hong Kong Polytechnic University academic Leung Ting interpreted the concept of sustainable development design as follows: "Sustainable development design is different from ordinary design. It only produces simple material products". It is a strategic design activity that combines products and services to create and develop sustainable solutions to meet the specific needs of consumers [19]. In 1992, the United Nations held the Conference on Environment and Development in Rio de Janeiro and the Conference on Population and Development in Cairo in 1994 to promote sustainable development among governments. Various disciplines have initiated extensive research on sustainable development, in accordance with their own characteristics, and many studies have been conducted on sustainable development design [20,21]. The research process can be roughly divided into four phases: (1) Sustainable design pays more attention to the intervention of results, i.e., solving existing problems, such as advocating waste reduction and recycling. This is called "green design" [22]. (2) Sustainable design extends from product impact to product focus. The concept of a product life cycle is presented. The artificial sustainable design concept should run through the whole process of product development, production, packaging, transportation, use, maintenance, recycling, and so on [23]. (3) Sustainable design extends from a product focus to a whole range of products and services. The theory of product service system innovation is put forward. At this point, sustainable design has shifted from a mere focus on products to a focus on issues. The solution to the problem can be a product or dematerialized service. The service system is characterized by dematerialization, efficient use of resources, optimization of product lifecycle, extension of material life, etc., and has great potential for environmental protection [24,25]. (4) The focus of sustainable design has shifted from environmental and ecological issues to broader social issues, i.e., promoting social equity and solidarity, cultural diversity, and local sustainable development to address root causes, such as a more environmentally friendly "consumption pattern", which includes sustainable designs of "lifestyles" conducive to social development and health [26,27].

2.2. Research on Bamboo Furniture

Bamboo has a long history. The bamboo forests in Asia and the Atlantic Ocean are the largest in the world. Bamboo species and forests account for 80% per cent of the world's area. While the world's forests are rapidly declining, bamboo forests are growing at a rate of 3% a year. At present, the area of bamboo forests in the world has reached 22 million hm^2, and annual production of bamboo timber production is 15–20 million tons [28,29]. Since bamboo is mainly distributed in Asia, especially in East and Southeast Asia, bamboo development and utilization are relatively common, and in China, Japan, Korea, and Southeast Asian countries, bamboo is a common raw material for making furniture. In Europe, relatively little research has been done on bamboo because it is very scarce, while research on bamboo in the Americas has mainly focused on its structure and properties [30–33]. The research on bamboo furniture in the early 21st century was mainly focused on research into the material properties of bamboo composite materials, the processing properties of bamboo furniture, and the development prospect of bamboo furniture [34,35]. Due to the large regional differences in the distribution of bamboo, the research on bamboo furniture also has large regional differences. More studies on bamboo furniture were conducted by Chinese scholars from 2018 to 2020 due to the protection of intangible crafts [36]. In India, research on bamboo furniture is mainly on the fiber aspects of bamboo, and research into bamboo furniture is mainly focused on raw bamboo furniture, which was studied and developed in a series by Sandeep Sangaroo (2011) [37]. In general, more international research has been focused on new materials for bamboo furniture, such as for the design of reconstituted bamboo furniture. Research from the perspective of dry shrinkage and wet swelling shows that reconstituted bamboo is suitable for use as a furniture manufacturing material. From the perspective of material bonding performance,

research confirms that the moment strength of reconstituted bamboo is higher than that of ordinary solid wood. From the perspective of material corrosion resistance, research shows that outdoor corrosion-resistant reconstituted bamboo has a broad development space [38–40]. Taken together, most scholars are optimistic about bamboo furniture's environmental performance and development potential, but there is a lack of systematic research on sustainable design, the environmental impact, and product evaluation.

2.3. Research on the Use of D4S Theory in Furniture Design

Under the guidance of D4S theory, furniture designers have discussed the application of various eco-friendly materials in furniture design. Common materials are corrugated paper, rattan, hemp, water grass, and grass planks [41,42]. One of the common features of these eco-friendly materials is that they have not become mainstream furniture materials; however, with the development of people's environmental protection awareness and processing technology, more and more furniture made from eco-friendly materials is produced. These furnishings not only meet the requirements of low-carbon, green, and eco-sustainable design, but also implement the principles of making the best use of materials, reducing consumption and recycling, achieving zero pollution and formaldehyde, and making it more possible for people to create a comfortable and healthy living environment [43]. Notably, bamboo furniture has contributed significantly to this goal.

At present, the research of furniture based on D4S theory mainly focuses on material selection, material evaluation, and sustainable consumption in the sustainable design methodology of furniture. Sustainable design is a design activity based on sustainable development aimed at achieving harmonious coexistence and sustainable development for people, nature, society, and ecology [44,45]. Furniture is indispensable in human social life. Its production, utilization, and disposal are closely related to the ecological environment and sustainable development. The goal of sustainable furniture design is to apply the core idea of sustainable design to furniture design activities.

3. Materials

This chapter focuses on the characteristics of bamboo materials and the bamboo product manufacturing process to give designers and producers a clearer and more comprehensive understanding of bamboo. In order to make better use of bamboo wood in the process of bamboo product design, we highlight the advantages of bamboo wood, promote the application of bamboo wood in the field of industrial design, and demonstrate the sustainable development of bamboo furniture.

3.1. Characteristics of Bamboo

Bamboo has good elasticity and flexibility, and fresh bamboo has good thermoplasticity, i.e., it can be bent and shaped by heating to produce a variety of chic bamboo products. The density of bamboo varies according to the age (more mature bamboo has a higher density), part (the tip section or culm wall edge has a higher density), and bamboo species, averaging approximately 0.64 g/cm^3. The dry shrinkage rate is lower than that of wood and it is anisotropic: the chordal dry shrinkage rate is the largest, the radial shrinkage rate is the second largest, and the longitudinal shrinkage rate is the smallest; water loss is fast and uneven when drying, thus diameter cracks easily form; air-dried bamboo is highly absorbent. The tensile strength of smooth grain is higher, approximately two times that of wood, and the tensile strength per unit weight is approximately 3–4 times that of steel; the shear strength of the smooth grain is lower than that of wood. When the moisture content is high, the compressive strength, tensile strength, shear strength, and radial bending strength of the smooth grain are lower. The texture becomes brittle, and the strength is lower when drying, but the cross-grain tensile strength, splitting strength, and chordal bending strength have no obvious effect. The strength gradually increases from the base of the culm upward: the outer edge of the culm wall (bamboo green) is stronger than the inner side (bamboo yellow), and the strength at the nodes (except for tensile strength) is slightly higher than

between the nodes [46,47]. In the early stages of growth, when the tissue density is low, bamboo is less strong. Bamboo strength generally varies according to its species and age. In general, as bamboo ages, the intensity increases to a certain stage and then decreases [48,49]. The properties of bamboo and other commonly used furniture materials are compared as follows (Table 2).

Table 2. Performance comparison of bamboo and other commonly used furniture materials.

Material	Physical and Mechanical Properties
Bamboo	Density 0.81 g/cm^3, coefficient of dry shrinkage 0.255%, tensile strength 184.27 MPa, flexural strength 108.52 MPa, compressive strength 65.39 MPa
Wood (oak)	Density 0.572 g/cm^3, dry shrinkage coefficient 0.392%, tensile strength 153.55 MPa, flexural strength 139.6 MPa, compressive strength 64.7 MPa
Plastic (PVC)	Density 0.9–2.3 g/cm^3, hardness $\geq$ 85 HR, tensile strength $\geq$ 36.8 MPa, bending modulus of elasticity $\geq$ 1961 MPa, Vicat softening point 83 °C, oxygen index 35%
Steel	Density 1.15 g/cm^3, tensile strength $\geq$ 300 MPa, compressive shrinkage strength $\geq$ 140 MPa, modulus of elasticity $\geq$ 30 GPa

3.2. The Processing Process of Bamboo Materials

Traditional bamboo raw materials are mainly applied in four forms: bamboo poles, bamboo slices, bamboo gabions, and bamboo strips (silk). The common bamboo raw material's main processing methods are sawing, scraping green, opening, splitting, drawing, steaming, carbonization, drying, etc. The traditional processing methods of bamboo materials have a low degree of mechanization, resulting in a lower production efficiency and mostly labor-intensive manual work. The traditional structure and process cannot realize the serialization, standardization, and generalization of products [36,50].

In the early 1800s, the first synthetic bamboo plywood appeared in China. The development of modern material integration technology has laid the foundation for the emergence of bamboo material integration. The bamboo material integration process mainly includes two key processes: first, in the pretreatment process of bamboo raw materials, the nutrients, bacteria, and moisture are removed from bamboo materials via steaming and charring processes, and, according to the requirements of the integrated materials of the bamboo, the raw materials are processed into bamboo chips, bamboo strips, or bamboo fiber bundles; second, in the integration process stage, the use of phenolic resin and other environmentally friendly adhesives requires a solid content of 60% or above, a viscosity of 30–50 Pa·s, a free formaldehyde content of less than 0.5%, and an amount of glue is generally controlled at approximately 200 g/m^2. Bamboo integration and wood integration are slightly different, with bamboo requiring a slightly higher hot-pressing time and pressure than wood. The division of labor of bamboo materials is becoming increasingly clear, and the upstream raw material supply directly provides bamboo chips, bamboo strips, bamboo wire, etc., to the downstream bamboo industry according to the requirements of the material processing preprocedure [51,52]. The different types of bamboo furniture are analyzed below (Table 3).

Table 3. Analysis of bamboo furniture.

Type	Figure	Description
Round bamboo furniture		The number and scale of enterprises specializing in the production of round bamboo furniture is small, and the output of individual family-type workshops accounts for the majority of the total output of such furniture. The non-disassembled structure of round bamboo furniture not only wastes raw materials but is also not conducive to quality control and product standardization, serialization, and disassembly, and leads to low production efficiency, high transportation costs, and a small product circulation.
Bamboo composite furniture		Bamboo laminated timber is produced with a certain hydrothermal carbonization treatment, and the finished product is well sealed, which can effectively prevent insect infiltration and mildew. Compared with wooden furniture, bamboo has strong physical and mechanical properties, and through a variety of applications of the material and rich color changes, it forms a diversity of styles to meet the needs of consumers at different levels.
Bamboo reconstituted furniture		Heavy bamboo is pressed and produced using a special process, sometimes involving high temperature, and has a very high density, super hardness, and static bending strength. Due to the restructuring of the fiber structure of bamboo, the external problem of deformation is completely solved. The bending is achieved in one piece and it can be a natural replacement for high-grade mahogany without any trace of articulation.
Bamboo bent and glued furniture		Bamboo bent and glued furniture mainly involves the use of bamboo, bamboo veneer, bamboo thin wood, and other materials, through the multilayer bending and gluing process.

4. Methods

This chapter firstly analyzes the specific objectives to be considered in furniture design with respect to the characteristics of sustainable design, and proposes a general strategy for sustainable furniture design in conjunction with the life cycle of the product, so as to provide a theoretical basis for later research. Then, specific design strategies are proposed to cope with the main bamboo problems according to the characteristics of bamboo. Finally, the specific design for bamboo furniture design is proposed from the perspective of the "human-environment-material" relationship methods, thus laying the foundation for sustainable design strategies of bamboo furniture to better guide design practice.

4.1. Goals and Strategies of Sustainable Design

For furniture design, the goal of sustainable design is not only to make furniture a sustainable product through design but also to consider the "sustainable" aspects of the production process of the furniture itself and the disposal method after it is abandoned [53–55]. Therefore, the goals of sustainable furniture design should be as follows: (1) from the point of view of the function of furniture, first, it should conform to ergonomics, and extend the life cycle of the product as far as possible while considering comfort. (2) From the point of view of furniture materials, it should make the best use of everything, follow the principle of sustainability, use natural ecological materials, and make furniture materials as natural and ecological as possible. (3) From the perspective of furniture production, it should ensure

a clean production process and minimize the damage and pollution to the environment. (4) From the perspective of furniture packaging, packaging materials are required to be nontoxic, easy to decompose, recyclable, and consider transportation costs and energy consumption. (5) From the perspective of the furniture sales process, the green marketing system should be adopted to reflect product characteristics.

With reference to the life cycle assessment theory of products and combined with bamboo furniture cases, the methods and strategies of sustainable furniture design are summarized as follows: (1) Selecting the material stage: No pollution or impact on the environment (emission of harmful gases, etc.) during use; choose materials that are renewable, degradable, and recyclable; select materials that are abundant in the area; choose materials with shorter growth cycles; choose ecological and green materials in the processing and manufacturing process; attempt to reduce material usage. (2) The design stage: Choose a sustainable structure design, refusing to complicate the structure; make disassembly and assembly more convenient and fast, and ensure it is convenient for flat packaging to save transportation space cost; ensure the easy repair and replacement of later parts, which is conducive to the recovery and reuse of discarded parts; ensure a multifunctional or modular design to improve the adaptability of furniture to extend the life of furniture, so the best use of everything is achieved, advancing the sustainable ecological concept. (3) The production stage: Minimize pollution; the waste, waste gas, and wastewater that cannot be avoided in the production process should be reduced to a minimum as much as possible, minimizing energy consumption, the consumption of materials, and various energy sources in the production process, and improving the material yield and reducing waste to the greatest extent. (4) The packaging stage: The principle of moderation should be adhered to as far as possible to reduce packaging materials; furniture packaging should be reused and reused for secondary sales; green packaging materials should be used, which can be recycled and decomposed naturally; choose strong wear-resistant, light weight, and pollution-free materials, with paper packaging now being the most appropriate material due to various comprehensive factors; choose the packaging material and process with less energy consumption and less material consumption. (5) The recovery and reuse stage: This stage depends on the material, waste product reprocessing and manufacturing, the recovery and reuse of old damaged parts, reducing the inevitable waste generated in the process of treatment, improving the recycling rate and the nonrecyclable parts to minimize their environmental pollution. The following design flow chart was created according to the above (Figure 1).

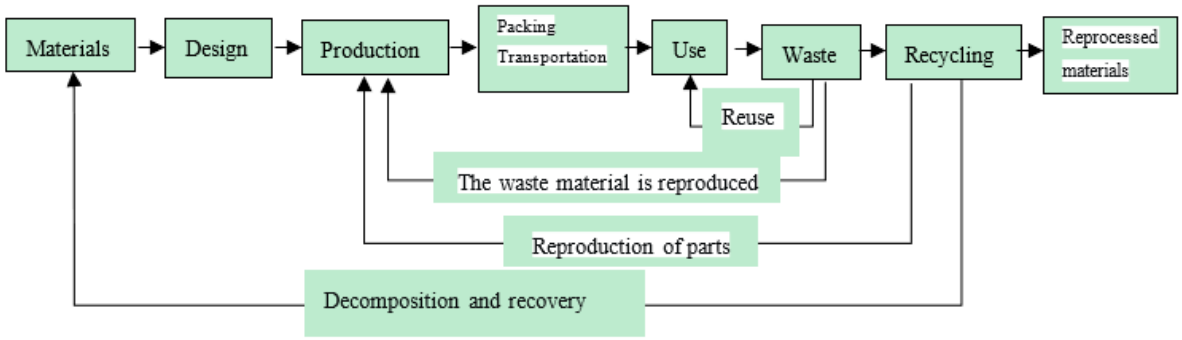


Figure 1. Design process.

4.2. Furniture Design Based on the Life Cycle of Bamboo

The life cycle assessment of products emphasizes the comprehensive consideration of the whole process from product development to scrap, even recycling, and analyzes and assesses the comprehensive environmental impact of the process as much as possible [56]. It includes the acquisition of raw materials, the processing and production of materials and accessories, assembly and packaging, transportation, use, and disposal after abandonment.

The environmental assessment and analysis is helpful to find the method of sustainable design that most reduces the impact of the whole process on the ecological environment, saves energy and resources, improves the usability and economy of products, and finally realizes the sustainable development of enterprises and the market [57]. The furniture design for the life cycle of bamboo can be mainly considered from the changes in the mechanical properties of bamboo, color changes, changes in the bamboo furniture after its damaged, packing portability, and other aspects.

4.2.1. Design Strategy to Address Mechanical Property Changes

From purchase, through use, to the end of the process, the physical properties of the material may produce a series of changes. Specifically, for the bamboo used in this design practice, consideration can be given to how the original bamboo can better perform its mechanical properties in different trial stages and states. This is to consider the sustainability of the life cycle of the furniture from the function of the furniture. The experimental study of the radial fracture characteristics of 3-year-old moso bamboo with a moisture content of 9.66% using the three-point bending test method showed that the fracture toughness of radially cracked moso bamboo specimens was 0.2–1.2 MPam$^{\frac{1}{2}}$ and gradually decreased with increasing crack depth. The fracture toughness of green bamboo was approximately 40% higher than that of yellow bamboo. As the number of bamboo nodes increases from the root to the tip, the diameter of bamboo gradually decreases, the length between nodes exhibits a parabolic distribution, and the radial fracture toughness decreases linearly [58].

4.2.2. Design Strategies to Cope with Color Texture Changes

Natural bamboo ware, i.e., bamboo ware made from raw bamboo, is only physically processed and shaped. It is not easy to control the color of this type of bamboo ware, as the color of the original bamboo is not simply the normal green color as appears on the outside, but may vary from yellow, white, to ebony after preparation. As long as the original bamboo ware is stored for a period of time and is used daily, the color will probably change in the following two main directions: from green (white) to yellow and finally to reddish-brown, due to the characteristics of the bamboo itself that determine the changes it undergoes as the environment changes. Therefore, we cannot simply judge yellow as the bamboo inner layer based on the color, or green as bamboo green. Bamboo green is not necessarily green. The way to determine whether it is bamboo green is to see whether there is a layer of substance like sodium on its surface. Reddish brown is the color change of the latter stage of high-quality natural bamboo. The other is from green (white) to yellow and then ebony. The black color occurs when the bamboo ware is not dried out in time after it is stored or used, it is immersed in water for a long time, or the bamboo used is young bamboo or bamboo from Yinshan, which will easily become moldy and black in later use. This kind of bamboo ware has little collection value and is mostly poor-quality bamboo ware. This is the problem we have to avoid in the design process. The color and texture of the bamboo itself will change as it ages and will also be affected by environmental changes in appearance. As the age of bamboo increases, the yellow and red color of the bamboo surface gradually becomes darker, while the brightness of the bamboo decreases slightly and the color becomes more calm and steady, e.g., from lime green and yellow–green to yellow, with black spots at a later stage. The different "colors" of bamboo have specific use value at different stages [59].

4.2.3. Design Strategies to Address Bamboo Cracking and Destruction

When a piece of bamboo furniture is completely damaged, it is possible to reuse it by processing it when it is split. For example, split bamboo can be used in a different form by splitting it into pieces, strips, or strands. With different forms of bamboo expression, the same material can be used in a new way with different forms. For example, in "Dandelion" in Figure 2 [60], the bamboo sticks are made using a handcraft technique to interlock and bite each other without other forms of connections, so that the characteristics of the bamboo

material are reflected in a unique and interesting way. During the production process, the designer splits one end of the bamboo stick and then hammers it to produce a dandelion-like form, after which each part is carefully layered to create a large "Ottoman-style" structure. The original hard material is wonderfully soft in appearance.

Figure 2. "Dandelion" bamboo furniture design.

4.2.4. Design Strategy to Cope with the Convenience of Packaging and Transportation

In the process of loading, unloading, and packing, bamboo furniture is packaged and stored into smaller, lighter, and less fragile parts to reflect the sustainable nature of bamboo furniture's lower loss of energy, the cost of labor, the space it takes up, the rate of breakage during transportation, the consumption of packing materials, and many other aspects of the transportation process. The concept of sustainable design is reflected in many aspects. This requires one to explore the design of structures that can meet the requirements of the above aspects based on the physical and chemical properties of the bamboo itself at the beginning of the design. A clever structure can often be disassembled to store the components of the furniture in a very limited space.

4.2.5. Design Strategies for Bamboo Recycling

Due to the fast growth of bamboo, many people regard bamboo as an inexhaustible material, which is mostly due to the one-sided perception of the growth cycle of bamboo. This results in the crude treatment of bamboo while we are designing and manufacturing bamboo furniture.

In fact, although the growth cycle of moso bamboo is very short and fast, it is not suitable for growth in all parts of the world due to its inherent heat flushing and moisture retention properties. In this paper, we focus specifically on Chinese moso bamboo. China's natural bamboo forest area of approximately 5 million hectares, which can produce up to an annual average of 500 million–600 million moso bamboos; however, the moso bamboo forest areas of Jiangxi, Fujian, Hunan, and Zhejiang provinces account for approximately 80% of the country's moso bamboo forest area or more [4]. Therefore, if we continue to follow our past uncontrolled and extensive abuse, bamboo itself, although a sustainable raw material, will still lead to reckless waste that will result in an oversupply of the raw material and eventually have serious consequences. We should try to reuse the discarded bamboo materials, for example, by breaking them up and remaking them into new synthetic materials after technical processing and by weaving them to make the best use of their value. In the city, we can establish enterprises related to discarded furniture, second-hand furniture, usable but discarded furniture materials for recycling and reuse, and the complete destruction of furniture to disassemble the recyclable parts for reorganization. It is hoped that through government support, materials can be properly disposed of and the concept of sustainable development can be more widely spread.

4.3. Sustainable Bamboo Furniture Design Based on "Human-Material-Environment" Relationship

(1) In styling, we need to consider the "destylization" of the shape. This is because too much stylization strictly limits the use of bamboo furniture in the environment. "Destyling"

means not attaching a specific style to the furniture and making it more universally adaptable. (2) Function: the reasonable conversion of function should be considered in combination with splitting or being extendable. After changing the use of the environment, the change of function of the same piece of furniture should be considered as far as possible, i.e., to promote multipurpose furniture. Small households change into large households, and space and household changes require a variety of uses. (3) The main structural points, i.e., the structural characteristics of bamboo itself, are the cylindrical nodal stalks. With strong adaptability, by adding a connector in the middle, you can make different bamboo poles connected together. This can also be done by sawing and changing the length. (4) Increase the combination of bamboo materials and other materials in bamboo furniture. Bamboo furniture does not necessarily mean that all bamboo materials must be used, and a single type of material furniture can easily form a certain exclusive style. In the concept of sustainable design, a particular style means that furniture design is treated in isolation, which is not conducive to considering the perspective of the relationship between furniture and people, furniture, and the environment. It is easy to associate natural materials such as bamboo and wood with styles such as Chinese traditional and Southeast Asian styles. Try to include metal, glass, acrylic, and other materials with different textures to improve the bamboo itself. Include strong style characteristics, so that the adaptability of bamboo furniture can be enhanced. Ensure that bamboo accounts for less than 70% of the whole volume of the furniture for visual effect [61].

5. Results and Discussion

On the one hand, this chapter elaborates on the practical aspects of the sustainable design of bamboo furniture in conjunction with the application of the sustainable design strategies proposed earlier. On the other hand, it creatively proposes a D4S-based bamboo furniture design evaluation method, which is an important theoretical study and practical guidance for the sustainable design of bamboo furniture.

5.1. Program Design Ideas

According to the analysis of D4S theory and bamboo furniture products, combined with the actual needs of furniture design, the innovative design ideas for this set of furniture were used to create the design concept diagram of the program (Figure 3). The design of the program mainly adopts the D4S product sustainable design method: a modular, standardized, multifunctional design, using bamboo integrated material and soft packaging; a simple manufacturing process, for easy mass production; simple, natural, and generous modeling, with a minimalist style; using basic functions and the expansion of powerful components, maintenance can be replaced; recycling aspects promote natural degradation, recovery, processing, and recycling.

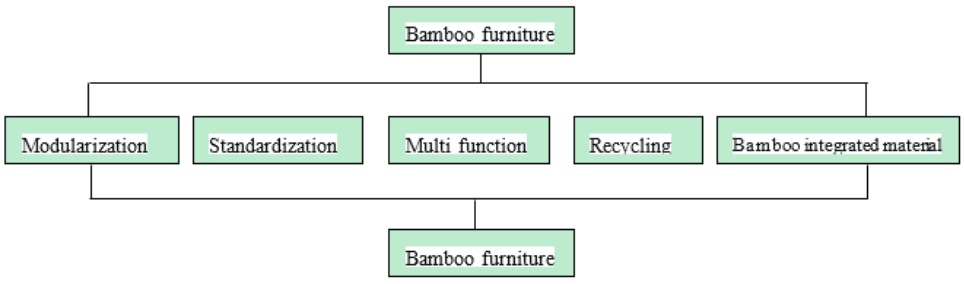


Figure 3. Design concept roadmap.

5.1.1. Design Methods Used

First, with D4S theory as the guide, the design must meet the principles of sustainable design. Second, sustainable design methods, including modularization, standardization, and multifunctional design, must be used so that the developed products are environmentally friendly, practical, beautiful, multifunctional, recyclable, and innovative. Finally,

this theory enables the products to achieve standardized production and save energy resources [62].

5.1.2. Design Strategies Adopted

An overall aesthetic was adopted with a systematic and local strategy. First of all, the preliminary design preparation and overall design target scheme fully considered the overall aesthetic factors of the product. Secondly, the whole design system of the product was standardized, so that every component of the product can be systematically produced. Then, using the localization strategy, the paper analyzed the existing bamboo forest resources in the area, shortened the distance between design, production, and consumption, and designed typical oriental style minimalist bamboo furniture.

5.1.3. Design Practice

Our team designed an outdoor bamboo furniture based on the D4S idea according to the previous design ideas and methods. Most of the modified solutions use the principle of bamboo fiber heating and the easy bending process. The whole piece of furniture was made of four monoliths of different heights, which are suitable for different users' needs, and each monolith can be arranged freely for many occasions. The end of each monomer was designed with a stainless-steel edge to facilitate furniture assembly. The design took into account the idea of sustainable design in the selection of materials, functional design, production, packaging, recycling, and other aspects (Figure 4).

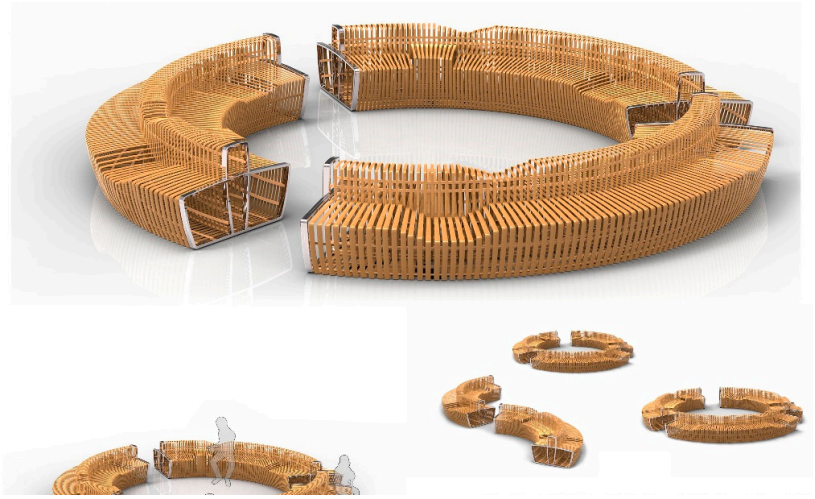


Figure 4. Modular outdoor bamboo furniture innovative design (author's design).

Bamboo furniture is not only a commonplace element in the environment but also a kind of craft. Its design requirements are as follows: be comfortable to use, have a solid structure and beautiful style, and be economical and easy to produce. Bamboo furniture is used to meet the needs of people's work, study, life, and other aspects, so the size of the human body, the basic size of each part, and the storage of the items must ensure the comfort and convenience. A standard size should be developed to meet the needs of the public, which is used as the basic basis for designing bamboo furniture. To make the structure of bamboo furniture strong and durable, in the design of the parts, more bamboo or more double bamboo should be used, i.e., two bamboo pieces can be glued together. In this way, when the bamboo material is dry, moisture absorption causes slight shrinkage and expansion, and the bamboo strips can offset each other and obtain a balance, thus reducing the overall deformation to enhance the solidity.

5.2. Design Evaluation

The entire D4S bamboo furniture product design process was evaluated by means of a design checklist based on actual conditions and existing conditions. For the program

we designed (Figure 4), 10 university experts and professors engaged in furniture product research, and 20 furniture product designers and 20 directors of related companies were invited to participate in this evaluation. A rapid evaluation of the project's compliance with sustainability was guaranteed. In the evaluation using the design checklist, the higher the score in the check result column, the higher the sustainability rating; conversely, the lower the score, the lower the sustainability rating. The results of the statistical scores are shown below (Table 4).

Table 4. Evaluation statistics results.

D4S Bamboo Furniture Design Check Results			
Evaluation date	4 October 2022	Sustainability rating	Level 2
Inspection items	Inspection content	Inspection result score	Total number of people selected
Design Solution Phase	① Maximum utilization of the characteristics of bamboo material	1 2 3 4 [5]	40
	② Maximum compliance with user needs	1 2 3 [4] 5	42
	③ Maximize business benefits	1 2 3 [4] 5	38
	④ No follow-up or corresponding efforts are required to ensure greenness	1 2 [3] 4 5	35
	⑤ Limited impact on the environment throughout the life cycle	1 2 [3] 4 5	34
Program Implementation Phase	① Use recyclable materials	1 2 3 4 [5]	45
	② Use as few materials as possible	1 2 3 4 [5]	43
	③ Easy to recycle	1 2 3 [4] 5	44
	④ Conform to production standards	1 2 3 [4] 5	46
	⑤ Lightweight processing and production	1 2 3 [4] 5	40
	⑥ Reduce the application of auxiliary materials such as ink, adhesive, bleach, dye, lamination, etc.	1 2 3 [4] 5	39
	⑦ Packaging materials are environmental protection materials	1 2 [3] 4 5	34
	⑧ Product environmental protection certification qualified	1 2 3 [4] 5	46
	⑨ Systematic, overall beauty, and localization strategies are implemented	1 2 3 [4] 5	44
Disposal Phase	① Recycled	1 2 3 [4] 5	46
	② Recycling	1 2 [3] 4 5	45
	③ Continuously consumed	1 2 3 [4] 5	42
	④ Naturally, degraded	1 2 3 [4] 5	48

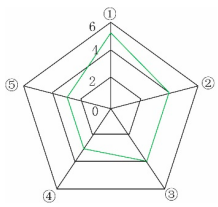
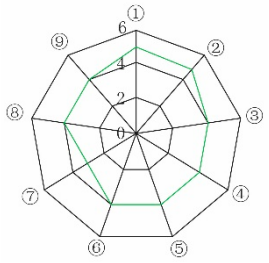
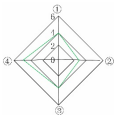
Note: 1—totally unsatisfied; 2—relatively unsatisfied; 3—satisfied; 4—relatively satisfied; 5—very satisfied. The number of boxes added indicates the average integer score of the evaluation results.

Through the calculation of the average formula, the sustainability grade in the design evaluation table is divided into five grades: the worst, bad, medium, good, and excellent, according to the average score. The analysis results were used to form a radar chart, which visually shows the advantages and disadvantages of each perspective in a clearl manner (Table 5).

$$\frac{A + B + C + \cdots + N}{n} \times 20$$

The evaluation results show that this product is qualified as an environmentally friendly furniture product and can be marketed as so. For the use of packaging materials, cardboard materials are now mostly used on the market; however, cardboard materials are difficult to recycle and cause great waste, so further research and exploration of packaging materials for bamboo furniture is needed. Thus, this aspect could not be seen as environmentally friendly. This product can be used as environmentally friendly furniture, but it is not certain whether it can contribute to sustainable consumption according to the results of the survey above. In fact, most consumers' knowledge of bamboo furniture is still insufficient, so strengthening people's knowledge of bamboo furniture should be a focus before bamboo furniture can contribute to sustainable consumption.

Table 5. Analysis of evaluation results.

Inspection Items	Inspection Content	Radar Chart of Examination Results Scores
Design Solution Phase	① Maximum utilization of the characteristics of bamboo material ② Maximum compliance with user needs ③ Maximize business benefits ④ No follow-up or corresponding efforts are required to ensure greenness ⑤ Limited impact on the environment throughout the life cycle	
Through the radar chart analysis, it can be intuitively seen that the experts, professors, furniture product designers, and business leaders were most satisfied with this solution because most people use the characteristics of bamboo wood to design furniture products with strong practicality.		
Program Implementation Phase	① Use recyclable materials ② Use as few materials as possible ③ Easy to recycle ④ Conform to production standards ⑤ Lightweight processing and production ⑥ Reduce the application of auxiliary materials such as ink, adhesive, bleach, dye, lamination. ⑦ Packaging materials are environmental protection materials ⑧ Product environmental protection certification qualified ⑨ Systematic, overall beauty, and localization strategies are implemented	
Through the analysis, it can be intuitively seen that the packaging material score of bamboo furniture was relatively low, which is not conducive to sustainable use. It is easy to waste packaging materials and, therefore, this needs further improvement.		
Disposal Phase	① Recycled ② Recycling ③ Continuously consumed ④ Naturally, degraded	
According to the analysis, the most important feature of the bamboo furniture was its natural degradation properties, and that it is easy to recycle and reuse; however, achieving sustainable consumption still requires the efforts of many parties.		

6. Conclusions

Based on our knowledge of sustainable design, this study provides an effective way to understand the application of bamboo resources in furniture design and the inevitable connection between bamboo and sustainable design through the study of bamboo, the bamboo industry, and bamboo furniture. Based on D4S theory, this paper establishes the theoretical framework of bamboo furniture product design and draws the following conclusions:

(1) By studying the basic theory of D4S, the methods and modes of bamboo furniture design that can be directly and effectively applied are summarized. First of all, the main design methods are based on bamboo life cycle analysis, which adopt a modular, standardized, multifunctional design. Secondly, the model of sustainable product design is established. The main steps are to set up a sustainable design team, collect sustainable design data, design sustainable product plans, make decisions on sustainable product design, establish a sustainable design enterprise alliance, and formulate sustainable design criteria for the industry;

(2) The article provides a general analysis of bamboo furniture and clarifies the advantages, disadvantages, and positive development prospects of bamboo furniture. With the increasing demand for environmentally friendly furniture and improvements in the production process, bamboo furniture breaks through the traditional shape and structure design, and new bamboo furniture emerges to provide more choices for people. Through our case study of bamboo furniture products, we learned that current bamboo furniture products are uneven and lack a design sense. In addition, although bamboo is environmentally friendly, bamboo furniture is not necessarily environmentally friendly. Thus, we proposed the D4S bamboo furniture design strategy, including a systematic and localized approach, which will play a very important role in guiding the sustainable design of bamboo furniture;

(3) The article concludes by inviting professionals to evaluate existing bamboo furniture products using a design checklist, which is professionally scored in three stages: design solution, solution execution, and disposal, and make a judgement based on the scores. This was used as an evaluation method applicable to D4S bamboo furniture product design to judge the sustainability of bamboo furniture product design.

This study is based on the theory of sustainable design and is an exploration of this theory in the field of bamboo furniture design. D4S bamboo furniture design is a complex system with a wide range of design content, which requires a great deal of knowledge to gradually improve. Due to the limited research conditions, I was unable to conduct a systematic study of the whole system, and only propose some practical methods and strategies. As I was unable to conduct an assessment of the whole systematic framework, there are still many aspects to be further improved and studied: (1) Only three representative methods applicable to D4S bamboo furniture design were selected; these are not perfect and need further research. (2) There are many strategies for sustainable design, but, in the article, I only selected three that I think are most suitable for the sustainable design of bamboo furniture; thus, the content of the strategies needs further improvement. (3) The design evaluation method proposed at the end of the article has not yet been demonstrated using more examples; thus, further research and improvement are needed in conjunction with specific practices. I hope that this study will establish a basic framework for D4S bamboo furniture design, point out the imperfections of this framework, and provide ideas and directions for subsequent research. In addition, I hope that this framework will become more complete and practical over time.

The research on this topic shows that D4S bamboo furniture product design is in line with the needs of the times and has great research value. The results of the article's analysis and the proposed methods and strategies are extremely feasible in reality; however, the support and collaboration of designers, enterprises, governments, and consumers is required to achieve the sustainable design of bamboo furniture and ultimately make the necessary contribution to improving human life and the environment.

Author Contributions: Conceptualization, W.D.; Methodology, W.D.; Software, W.D.; Resources, W.D.; Data curation, M.J.; Writing—original draft, W.D.; Writing—review & editing, M.J.; Supervision, H.L.; Project administration, W.D.; Funding acquisition, W.D. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Modarress, B.; Ansari, A.; Ansari, A. Sustainable Development and Ecological Deficit in the United Arab Emirates. *Sustainability* **2020**, *12*, 6180. [CrossRef]
2. Aykut, S.C.; Maertens, L. The climatization of global politics: Introduction to the special issue. *Int. Politics* **2021**, *58*, 501–518. [CrossRef]

3. Bouraiou, A.; Necaibia, A.; Boutasseta, N.; Mekhilef, S.; Dabou, R.; Ziane, A.; Sahouane, N.; Attoui, I.; Mostefaoui, M.; Touaba, O. Status of renewable energy potential and utilization in Algeria. *J. Clean. Prod.* **2020**, *246*, 119011. [CrossRef]
4. Dlamini, L.C.; Fakudze, S.; Makombe, G.G.; Muse, S.; Zhu, J. Bamboo as a valuable resource and its utilization in historical and modern-day China. *BioResources* **2021**, *17*, 1926–1938. [CrossRef]
5. Gan, J.; Chen, M.; Semple, K.; Liu, X.; Dai, C.; Tu, Q. Life cycle assessment of bamboo products: Review and harmonization. *Sci. Total Environ.* **2022**, *849*, 157937. [CrossRef] [PubMed]
6. Muhammad Suandi, M.E.; Amlus, M.H.; Hemdi, A.R.; Abd Rahim, S.Z.; Ghazali, M.F.; Rahim, N.L. A Review on Sustainability Characteristics Development for Wooden Furniture Design. *Sustainability* **2022**, *14*, 8748. [CrossRef]
7. Bumgardner, M.S.; Nicholls, D.L. Sustainable Practices in Furniture Design: A Literature Study on Customization, Biomimicry, Competitiveness, and Product Communication. *Forests* **2020**, *11*, 1277. [CrossRef]
8. Wang, Y.; Liu, C.; Zhang, X.; Zeng, S. Research on Sustainable Furniture Design Based on Waste Textiles Recycling. *Sustainability* **2023**, *15*, 3601. [CrossRef]
9. Ratnasingam, J.; Ioras, F. The sustainability of the Asian wooden furniture industry. *Holz. Als. Roh. Werkst.* **2003**, *61*, 233–237. [CrossRef]
10. Siti Suhaily, S.; Islam, M.N.; Asniza, M.; Rizal, S.; Abdul Khalil, H.P.S. Physical, mechanical and morphological properties of laminated bamboo hybrid composite: A potential raw material for furniture manufacturing. *Mater. Res. Express* **2020**, *7*, 7. [CrossRef]
11. Sun, Y.; Gong, J.; Liu, H.; Fang, C. Axial Compression Behaviors of Columns Fabricated from Bamboo Oriented Strand Boards. *Forests* **2022**, *13*, 1817. [CrossRef]
12. Xiong, X.; Ma, Q.; Yuan, Y.; Wu, Z.; Zhang, M. Current situation and key manufacturing considerations of green furniture in China: A review. *J. Clean. Prod.* **2020**, *267*, 121957. [CrossRef]
13. Corsini, L.; Moultrie, J. What Is Design for Social Sustainability? A Systematic Literature Review for Designers of Product-Service Systems. *Sustainability* **2021**, *13*, 5963. [CrossRef]
14. Rocha, C.S.; Antunes, P.; Partidário, P. Design for sustainability models: A multiperspective review. *J. Clean. Prod.* **2019**, *234*, 1428–1445. [CrossRef]
15. Schoenmaker, D. *Principles of Sustainable Finance*; Oxford University Press: Oxford, UK, 2019.
16. Silvestre, B.S.; Ţîrcă, D.M. Innovations for sustainable development: Moving toward a sustainable future. *J. Clean. Prod.* **2019**, *208*, 325–332. [CrossRef]
17. Wojtkowiak, D.; Cyplik, P. Operational Excellence within Sustainable Development Concept-Systematic Literature Review. *Sustainability* **2020**, *12*, 7933. [CrossRef]
18. Navarrete, S.D.S.; Borini, F.M.; Avrichir, I. Environmental upgrading and the United Nations Sustainable Development Goals. *J. Clean. Prod.* **2020**, *264*, 121563. [CrossRef]
19. Leong, B.D.; Lee, B.Y.H. Future Shade of Green: Introduction to the Practice of "Product Design for Sustainability". *J. Zhuangshi* **2013**, *242*, 31–38.
20. Filimonova, I.V.; Provornaya, I.V.; Komarova, A.V.; Zemnukhova, E.A.; Mishenin, M.V. Influence of economic factors on the environment in countries with different levels of development. *Energy Rep.* **2020**, *6*, 27–31. [CrossRef]
21. Ghabbour, S.I. United Nations International Conference on Population and Development (ICPD), held in the International Conference Centre, Cairo, Egypt, during 5–13 September 1994. *Environ. Conserv.* **2009**, *21*, 283–284. [CrossRef]
22. Moro, S.R.; Cauchick-Miguel, P.A.; Campos, L.M.S. Product-service systems towards eco-effective production patterns: A Lean-Green design approach from a literature review. *Total Qual. Manag. Bus. Excell.* **2019**, *32*, 1046–1064. [CrossRef]
23. Zhang, X.; Zhang, L.; Fung, K.Y.; Bakshi, B.R.; Ng, K.M. Sustainable product design: A life-cycle approach. *Chem. Eng. Sci.* **2020**, *217*, 115508. [CrossRef]
24. Kristensen, H.S.; Remmen, A. A framework for sustainable value propositions in product-service systems. *J. Clean. Prod.* **2019**, *223*, 25–35. [CrossRef]
25. Meier, H.; Roy, R.; Seliger, G. Industrial Product-Service Systems—IPS 2. *CIRP Ann.* **2010**, *59*, 607–627. [CrossRef]
26. Piligrimienė, Ž.; Banytė, J.; Dovalienė, A.; Gadeikienė, A.; Korzilius, H. Sustainable Consumption Patterns in Different Settings. *Eng. Econ.* **2021**, *32*, 278–291. [CrossRef]
27. Yates, L. Sharing, households and sustainable consumption. *J. Consum. Cult.* **2016**, *18*, 433–452. [CrossRef]
28. Tamang, M.; Nandy, S.; Srinet, R.; Das, A.K.; Padalia, H. Bamboo Mapping Using Earth Observation Data: A Systematic Review. *J. Indian Soc. Remote Sens.* **2022**, *50*, 2055–2072. [CrossRef]
29. Fadrique, B.; Santos-Andrade, P.; Farfan-Rios, W.; Salinas, N.; Silman, M.; Feeley, K.J. Reduced tree density and basal area in Andean forests are associated with bamboo dominance. *For. Ecol. Manag.* **2021**, *480*, 118648. [CrossRef]
30. Du, H.; Mao, F.; Li, X.; Zhou, G.; Xu, X.; Han, N.; Sun, S.; Gao, G.; Cui, L.; Li, Y.; et al. Mapping Global Bamboo Forest Distribution Using Multisource Remote Sensing Data. *IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens.* **2018**, *11*, 1458–1471. [CrossRef]
31. Feng, X.; Tan, S.; Dong, Y.; Zhang, X.; Xu, J.; Zhong, L.; Yu, L. Mapping Large-Scale Bamboo Forest Based on Phenology and Morphology Features. *Remote Sens.* **2023**, *15*, 515. [CrossRef]

32. Ferreira, E.; Kalliola, R.; Ruokolainen, K. Bamboo, climate change and forest use: A critical combination for southwestern Amazonian forests? *Ambio* **2020**, *49*, 1353–1363. [CrossRef] [PubMed]
33. Qi, S.; Song, B.; Liu, C.; Gong, P.; Luo, J.; Zhang, M.; Xiong, T. Bamboo Forest Mapping in China Using the Dense Landsat 8 Image Archive and Google Earth Engine. *Remote Sens.* **2022**, *14*, 762. [CrossRef]
34. Muhammad, A.; Rahman, M.R.; Hamdan, S.; Sanaullah, K. Recent developments in bamboo fiber-based composites: A review. *Polym. Bull.* **2018**, *76*, 2655–2682. [CrossRef]
35. Lou, Z.; Wang, Q.; Sun, W.; Zhao, Y.; Wang, X.; Liu, X.; Li, Y. Bamboo flattening technique: A literature and patent review. *Eur. J. Wood Wood Prod.* **2021**, *79*, 1035–1048. [CrossRef]
36. Luo, B.; Ahmed, S.; Long, C. Bamboos for weaving and relevant traditional knowledge in Sansui, Southwest China. *J. Ethnobiol. Ethnomed.* **2020**, *16*, 63. [CrossRef]
37. Huang, D. Know "bamboo". *ZHUANGSHI* **2011**, *11*, 36–41.
38. Han, X.; Lou, Z.; Yuan, C.; Wu, X.; Liu, J.; Weng, F.; Li, Y. Study on the Effect of Two-Step Saturated Steam Heat Treatment Process on the Properties of Reconstituted Bamboo. *J. Renew. Mater.* **2022**, *10*, 3313–3334. [CrossRef]
39. Yang, L.; Lou, Z.; Han, X.; Liu, J.; Wang, Z.; Zhang, Y.; Wu, X.; Yuan, C.; Li, Y. Fabrication of a novel magnetic reconstituted bamboo with mildew resistance properties. *Mater. Today Commun.* **2020**, *23*, 101086. [CrossRef]
40. Zhao, K.; Wei, Y.; Chen, S.; Hang, C.; Zhao, K. Experimental investigation of the long-term behavior of reconstituted bamboo beams with various loading levels. *J. Build. Eng.* **2021**, *36*, 102107. [CrossRef]
41. Gu, Y.; Zhang, J. Tensile Properties of Natural and Synthetic Rattan Strips Used as Furniture Woven Materials. *Forests* **2020**, *11*, 1299. [CrossRef]
42. Kremensas, A.; Vaitkus, S.; Vėjelis, S.; Członka, S.; Kairytė, A. Hemp shivs and corn-starch-based biocomposite boards for furniture industry: Improvement of water resistance and reaction to fire. *Ind. Crops Prod.* **2021**, *166*, 113477. [CrossRef]
43. Yasir, M.; Majid, A.; Yasir, M.; Qudratullah, H. Promoting environmental performance in manufacturing industry of developing countries through environmental orientation and green business strategies. *J. Clean. Prod.* **2020**, *275*, 123003. [CrossRef]
44. Sun, X. Green and ecological interior design based on network processor and embedded system. *Microprocess. Microsyst.* **2021**, *82*, 103911. [CrossRef]
45. Li, H.; Wen, K.-H. Research on Design of Stalk Furniture Based on the Concept and Application of Miryoku Engineering Theory. *Sustainability* **2021**, *13*, 3652. [CrossRef]
46. Gao, X.; Zhu, D.; Fan, S.; Rahman, M.Z.; Guo, S.; Chen, F. Structural and mechanical properties of bamboo fiber bundle and fiber/bundle reinforced composites: A review. *J. Mater. Res. Technol.* **2022**, *19*, 1162–1190. [CrossRef]
47. Kadivar, M.; Gauss, C.; Ghavami, K.; Savastano, H., Jr. Densification of Bamboo: State of the Art. *Materials* **2020**, *13*, 4346. [CrossRef]
48. Zhu, Y.; Huang, J.; Wang, K.; Wang, B.; Sun, S.; Lin, X.; Song, L.; Wu, A.; Li, H. Characterization of Lignin Structures in Phyllostachys edulis (Moso Bamboo) at Different Ages. *Polymers* **2020**, *12*, 187. [CrossRef]
49. Wi, S.G.; Lee, D.S.; Nguyen, Q.A.; Bae, H.J. Evaluation of biomass quality in short-rotation bamboo (Phyllostachys pubescens) for bioenergy products. *Biotechnol. Biofuels* **2017**, *10*, 127. [CrossRef]
50. Akoto, D.; Denich, M.; Partey, S.; Frith, O.; Kwaku, M.; Mensah, A.; Borgemeister, C. Socioeconomic Indicators of Bamboo Use for Agroforestry Development in the Dry Semi-Deciduous Forest Zone of Ghana. *Sustainability* **2018**, *10*, 2324. [CrossRef]
51. Huang, Y.; Qi, Y.; Zhang, Y.; Yu, W. Progress of Bamboo Recombination Technology in China. *Adv. Polym. Technol.* **2019**, *2019*, 1–10. [CrossRef]
52. Mofidi, A.; Abila, J.; Ng, J.T.M. Novel Advanced Composite Bamboo Structural Members with Bio-Based and Synthetic Matrices for Sustainable Construction. *Sustainability* **2020**, *12*, 2485. [CrossRef]
53. Tsolakis, N.; Niedenzu, D.; Simonetto, M.; Dora, M.; Kumar, M. Supply network design to address United Nations Sustainable Development Goals: A case study of blockchain implementation in Thai fish industry. *J. Bus. Res.* **2021**, *131*, 495–519. [CrossRef]
54. Chen, F.-H.; Ho, S.-J. Designing a Board Game about the United Nations' Sustainable Development Goals. *Sustainability* **2022**, *14*, 11197. [CrossRef]
55. Campbell, D.A. An Update on the United Nations Millennium Development Goals. *J. Obstet. Gynecol. Neonatal. Nurs.* **2017**, *46*, e48–e55. [CrossRef]
56. Pryshlakivsky, J.; Searcy, C. Life Cycle Assessment as a decision-making tool: Practitioner and managerial considerations. *J. Clean. Prod.* **2021**, *309*, 127344. [CrossRef]
57. Athar, M.; Shariff, A.M.; Buang, A. A review of inherent assessment for sustainable process design. *J. Clean. Prod.* **2019**, *233*, 242–263. [CrossRef]
58. Wang, F.; Shao, Z.; Wu, Y.; Wu, D. The toughness contribution of bamboo node to the Mode I interlaminar fracture toughness of bamboo. *Wood Sci. Technol.* **2013**, *48*, 1257–1268. [CrossRef]
59. Wang, X.; Liang, D.; Deng, W. Surface grading of bamboo strips using multi-scale color texture features in eigenspace. *Comput. Electron. Agric.* **2010**, *73*, 91–98. [CrossRef]
60. Designers Use Sharp Skewers to Create Soft 'Dandelions'. Available online: https://www.sohu.com/a/481513783_121124644 (accessed on 26 March 2023).

61. Wan, Q.; Hu, Q.; Chen, B.; Fang, H.; Ke, Q.; Song, S. Study on the Visual Cognition of Laminated Bamboo Furniture. *For. Prod. J.* **2021**, *71*, 84–91. [CrossRef]
62. Glavič, P. Updated Principles of Sustainable Engineering. *Processes* **2022**, *10*, 870. [CrossRef]