Exploration of Product Innovation Ideas Based on the Relationship Between Science and Design

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Abstract. As society progresses and people's quality of life improves, China is transforming and upgrading from product manufacturing to product creation. The two aspects that have a great impact on modern life are science and design. They play an important role in the transformation and upgrading of product creation. In this paper, the definitions of science and design are summarized. An overview is given about the development and application of science and design in China and globally. Through the analysis of the interrelationship between science and design, the impact of modern science and technology on design is identified – the application of modern science and technology can improve human-computer interaction and enhance the user experience of product design. By combining the six design dimensions of "5W1H", we propose the idea of product innovation based on science and design. Through the innovation of product design from the perspective of science and technology, it not only improves the quality and value of the product, but also provides new inspirations for designers. In addition, the design methodology proposed in this study is applied to express and embody the theories through design cases. The research results show that science and design as a special element of human-computer interaction design. It has a positive value to the breakthrough of product creation and can further promote the mutual integration and common progress of science and design.

Keywords: science and design · product innovation · human-computer interaction · product design

1 Introduction

As history progresses, it can be understood that there is a relationship between science and design. The issue of the relationship between science and design has always been a hot topic of conversation. Science is the intellectual activity of human beings to understand the world, nature, society and self. Design is the creative activity of human emotion expression, aesthetic appreciation and communication. Different people have different opinions about the definition of science and design, and there is no definite answer. The breakthrough and development of science will promote the development of design. At the same time, the development of design will also require higher-end science, thus promoting the development of science. There is a complex relationship between science and design that promotes, facilitates and develops each other.

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The relationship between the two is complex due to the wide range of disciplines involved. And the related research lacks practicality and relevance. Therefore, it is difficult for junior designers to grasp and utilize the role of science in design. The purpose of this paper is to summarize the interrelationship between science and design, and propose product innovation ideas based on the relationship between science and design to achieve a better human-computer interaction experience. The theory will guide the practice and provide more design inspiration for designers.

For junior designers, it seems that design is always limited to the appearance of the design. As people enter the era of "digitalization". The former state of two-dimensional design is constantly being impacted by three-dimensional and four-dimensional design. Designers are constantly searching for new fields. Due to the support of science, designers' thinking also continues to find inspiration for breakthroughs in other fields [1]. Junior designers are often confused and overwhelmed when designing the relationship between science and design. Therefore, as designers should first have a deeper understanding of science and design.

The intersection and use of science and design can bring a stronger visual impact to the design work. It also brings more possibilities of interaction between human and machine, and gives the design connotation and contemporary value. Therefore, science is one of the important factors to consider when designing products. This paper proposes a product innovation idea based on the relationship between science and design.

The paper is structured as follows. First, the relevant literature on the relationship between science and design is summarized. Based on this, a design idea based on a scientific perspective is proposed for designers. Finally, an application of this idea is carried out.

2 Literature Review

2.1 Definition

Academia has not developed a unified understanding of either science or design.

Regarding the definition of design, Morris Asimow proposed, "Design is a high-risk decision-making process under conditions of uncertainty [2]". Wojciech Gasparski states, "Design is an activity that aims to improve reality [3]". In Christopher Jones' opinion, "Design is about making man-made objects change [4]". Bruce Archer believes that "Design is an activity that seeks to solve a problem for a target [5]". Herbert Simon sees design in this way: "What design is concerned with is the discovery and careful construction of alternatives [6]". Klaus Krippendorff asserts, "Design is a conscious creation of form for human needs [7]". Rigomant believes that "design is a social mediation activity [8]". Rosman and George argue that "design is a purposeful human activity that uses cognitive processes to transform human needs and intentions into materialized entities". Zeng Yong emphasized that "design is the process of simultaneously producing artificial objects and their behavioral systems [9]".

Based on the key words extracted from these perspectives, the following key words can be used to describe the view of design: "decision making", "activity", "change," "solving activity", "discovery and construction", "form creation", "mediation activity", "transformation", and "emergent process".

The definitions of design can be broadly classified into five categories based on key words:

a. Design is an activity about decisions and choices.
b. Design is a problem solving activity.
c. Design is a creative activity.
d. Design is the activity of transforming nature into artifacts [10].
e. Design is a mental activity that creates a desired situation from existing reality [11].

Regarding the definition of science, Wikipedia describes it this way: "Science, a systematic system of knowledge that constructs knowledge about the universe in a testable explanatory and predictive manner [12]". In the Dictionary is explained this way: "Science refers to the system of knowledge that reflects the nature and laws of various phenomena in the real world using categories, theorems, laws and other forms of thinking [13]". The president of the Chinese Academy of Sciences, writing in the first issue of Science and Technology Tide in 1998, pointed out that "the essence of science is to constantly create new knowledge and pursue new truths [14]".

Science is the body of knowledge by which humans understand nature, society, and their own physiology, psychology, and thinking. This human intellectual pursuit is usually characterized by rationality. From a lexical point of view, "science" as a noun can be interpreted as an intelligent act to better understand the world, leading to a novel, significant, and well-founded norm; "science" as a verb can be seen as performing an intelligent act.

2.2 Differences and Connections

The distinction and connection between art and science was highly summarized by the 19th century French scientist Claude Bernard in the first person singular and plural: "Art is I, science is we".

Design is a designer's creative activity based on available materials and manipulable tools. Under the role of thinking, the creative activity is carried out by digesting the existing scientific and technological civilization. Design is both art and science. It is a cross-discipline of science, technology and art [15].

Both science and design are essentially exploratory activities, a process of continuous innovation and solution seeking.

2.3 Development and Application

With the progress of modern technology and civilization, it makes the relationship between science and design closer and closer.

Science and design have been used in China since the Western Han Dynasty. The Western Han Dynasty's Changxin Palace Lamp is in line with modern "ergonomics" and "human-centered" design concepts. It uses a rainbow tube to absorb the smoke of the lamp and send it to the lamp base, dissolving it in water. The lamp is 48 cm high, with a scientific structure and appropriate scale, and the light irradiation range is basically suitable for people's eyes when sitting on their knees. The design of the lampshade not only has the function of reflection and concentration of light, but also can adjust the

angle and illumination of the light through the opening and closing of the lampshade [16].

The Renaissance is also able to represent well the integration of science and design. During this period, the representative figure was Leonardo da Vinci. He was profoundly thoughtful and knowledgeable. His design practice and the spirit of scientific exploration had a profound impact on later generations [17].

Modern abstractionists, futurists and surrealists advocated the use of various achievements of modern natural sciences, such as relativity and quantum mechanics in their works. Since the 1920s, many new schools and trends of design, structural mechanics, applied mechanics, material science, construction techniques and other revolutionary achievements have emerged. Until the widespread use of computers, new paths were opened for the original practice of design. Modern buildings such as the Brussels Atomium, the Sydney Opera House and the Pompidou Center for Art and Culture are examples of the fusion of science and design.

3 The Interrelationship Between Science and Design

The development of design applies scientific innovation tools and theories to accelerate the effectiveness of product creation, enrich creative inspiration, and achieve innovation in product design. The ultimate goal of both science and design is to better serve humanity [18]. Design and science, as branches of the discipline, belong to the same philosophy. And then with the refinement of the discipline, more and more branches of the discipline are separated from philosophy. Between science and design, they are crossed, related and intergraded, both independent and connected [19]. Therefore, art and science have endless overlap and crossover, and the two are full of dialogue and conflict [20].

3.1 Science Triggers Design Innovation

a. Science has changed the way of thinking about design

Science and design originate together from people's material production practice. Science has created human material civilization, while design has created human spiritual civilization [21]. Science brings more ways of thinking and expression to design forms, and AI artificial intelligence has become popular in recent years. Artificial intelligence-assisted design such as CHATGPT and Midjourney has changed the design thinking and design process of some designers.

b. Science has created more possibilities for design

Science is present throughout Chinese history. The innovation of products, design aspects and product forms are based on a certain scientific basis. The "porcelain" that can symbolize China can well present this in its development process. China's porcelain technology advances, from the original form of a single colorless porcelain type transition to an all-encompassing, regional characteristics and integration of porcelain. In some selection of materials, molding and artistic processing has reached a high level of technology, but

also the crystallization of the level of science and technology at the time. In the gradual development of science on the basis of the development of porcelain design, while ancient China on top of the continuous development of science to have the ancient Silk Road porcelain trend, to have porcelain transported to Western countries to become a symbol of identity of the upper class people in Western countries [22].

In today's high-speed development, science and technology are changing rapidly, 5G technology, 4D printing technology, 4K aerial camera, VR holographic technology and new materials and new energy [23], all provide new ways of presentation and new forms of human-computer interaction for art, creating more possibilities for design.

3.2 Design Pulls Science Forward

The success of the Sonnet chair is a typical example. At the beginning of the industrial revolution, handcrafted products were beautiful, ornate and contained a lot of curves. The industrial revolution swept in, and mechanized production methods righteously replaced the manual production methods. However, the new mechanical tools did not meet the design requirements. To enable mechanized woodworking techniques to produce beautiful curved shapes, German furniture craftsman Michael Thonet invented the steam bent wood process. The new product shape and the affordable selling price achieved the great success of Thonet chair.

When science fails to meet the needs of design, it drives the development of related sciences. It leads to new product opportunities, simplified processing and lower production costs.

3.3 Science and Design Develop Together

Science permeates all stages of product design, and product design continues to reveal the role and connotation of science. First, the tools used in contemporary design activities come from the results of scientific and technological research, such as computer-aided design hardware and software, supporting intelligent devices and their related technologies. Secondly, one of the sources of inspiration for design activities is science. Finally, scientific theory is the theoretical basis for design.

Design and science both in step, coordinated development, to achieve a virtuous cycle of innovation and development. So that the product development and manufacturing business all the way to open up, and constantly generate new human material and spiritual civilization.

4 Design Idea

This section provides designers with an idea for product design that incorporates science. The idea is based on the relationship between science and design.

Design is not just about the appearance of a product, but a comprehensive planning of the product. Designers create products that uniquely satisfy users according to their functional and psychological needs, and in response to the requirements of the times. All this is supported by science and technology, and product design thinks about how to translate the new science and technology into social life. One of the mediums between these is human-computer interaction. The development of science has also brought more options for human-computer interaction.

Human-computer interaction aims to achieve a natural, efficient, and harmonious human-computer relationship, and to study the technology of human, computer, and two-way information exchange between them [24]. With the development of science, some new technologies have enriched the expression of human-computer interaction. However, so far there is no systematic approach for an introductory understanding by junior designers.

In 1932, the American political scientist Lasswell proposed the "5W1H analysis method". This method is widely used in design and is easy to understand. So in this paper, we want to combine this analysis method and propose a design idea that uses the interrelationship between science and design (see Fig. 1). And the "who/when/where-why-what-who" recycling pattern is formed (see Fig. 2).

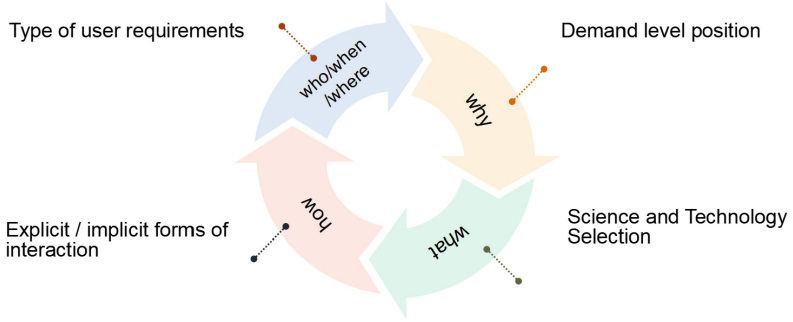

Fig. 1. Circular model based on "5W1H".

4.1 Using Crowd Analysis

Analyzing the psychological and physical characteristics of users, clarifying the environment in which the product is located can help designers find the actual pain points. It can be combined with methods such as empathy map and user journey map as a starting point. Grasp the user needs, product use scenarios, and product usage, and seek the optimal solution to match the needs and functions. Locate the specific functions of the product and clarify the interaction methods.

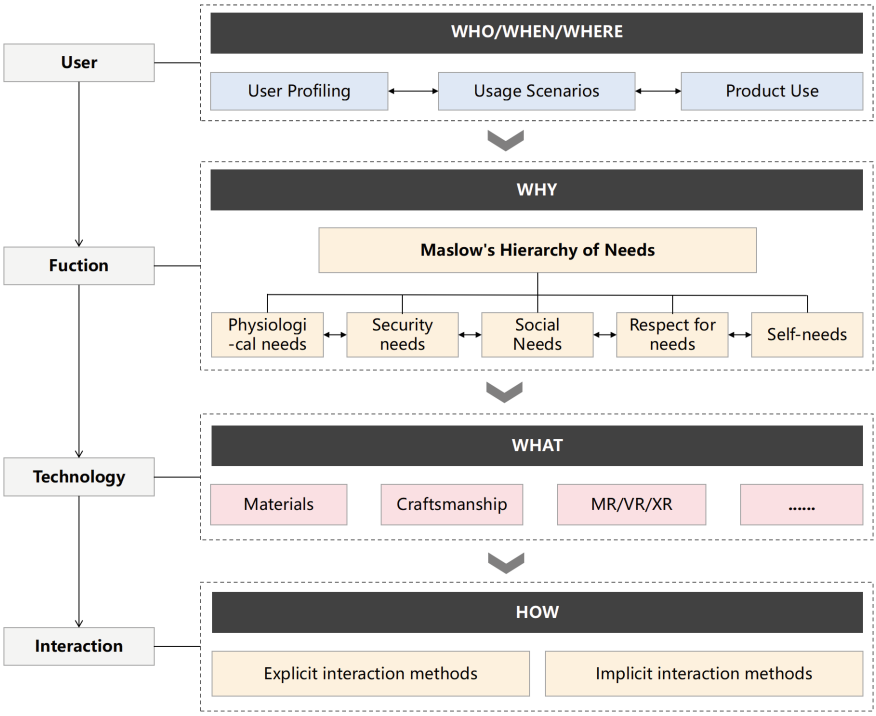

Fig. 2. Design thinking at the intersection of science and design.

4.2 Design Positioning to Meet Core Demand Levels

The core of human-computer interaction is to meet the needs of users. Studying the core needs of users can optimize the human-computer interaction and thus improve the user experience of users.

The American psychologist Maslow proposed the Maslow's Hierarchy of Needs in 1943, which divides human needs into five levels. From low to high: physiological, security, social, respect and self-actualization needs. These five levels develop from low to high. When many needs are not met, it is more urgent to meet the lower level needs. After a certain level of needs is satisfied, people will seek higher levels of satisfaction. The relationship between each level of needs is cross-over [25]. Based on the user needs, product usage scenarios, and product uses in the previous step, the core functions as well as the secondary functions of the product can be initially determined.

4.3 Selecting a Suitable Scientific Vehicle

After determining the design positioning of the product, it is important to choose the appropriate scientific and technological vehicle.

The choice of carrier and product function are closely related. On the one hand, the designer can find the relevant science and technology suitable for the solution according to the product function; on the other hand, the designer can also think out of the box

according to the advanced technology to create more avant-garde works. Designers should keep pace with the times and keep up with the development of science. On the basis of the minimum amount of loss, the optimal human-computer interaction experience is achieved.

4.4 The Combined Effect of Explicit and Implicit Interaction Methods

The current interaction process is mostly command-based. Human-computer interaction by the device user through keyboard, mouse, gestures and voice commands is called explicit interaction. Implicit interaction, on the other hand, is defined by Schmidt as invisible interaction [26]. The explicit and implicit interactions are distinguished by two dimensions, device initiative and user attention [27] (see Fig. 3).

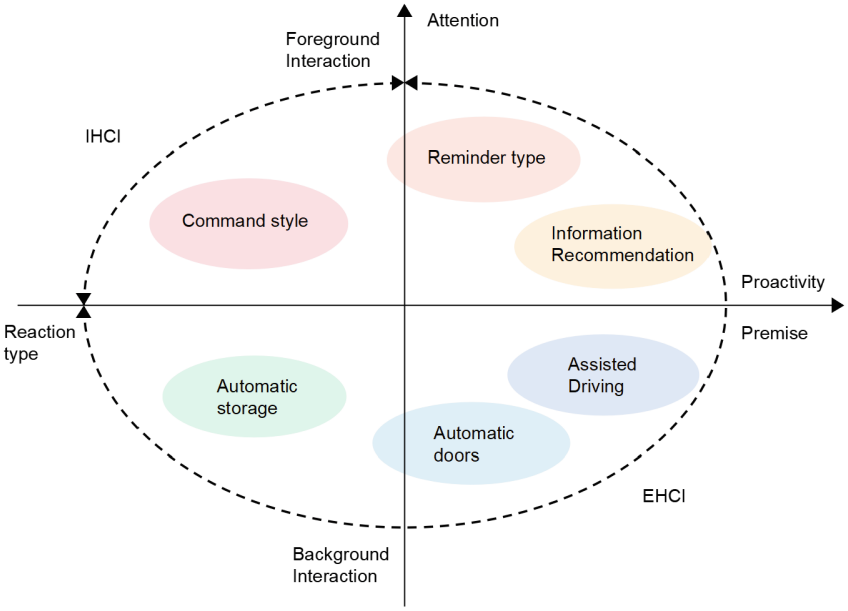

Fig. 3. EHCI and IHCI.

Explicit and implicit interaction methods are interrelated to make the whole human-computer interaction process natural and smooth, while expanding the dimensions of human-computer interaction methods. The design method of using explicit and implicit interaction methods together in the design process can improve the efficiency of human-computer interaction for core functions [28].

5 Application of Ideas

The home growing robot "SHUBAN" is based on the above design idea. It is designed to meet the needs of children and people at home. It uses biodegradable household waste as composting material to meet the needs of growing green vegetables at home. Through MR technology, it can interact with people and visualize the needs of plants (see Fig. 4).

Fig. 4. The effect of "SHUBAN".

The top is a 7-in. LCD screen for displaying the needs of the plant. Through the MR device projection, it can observe the MR genie above the plant. The MR genie will respond to the state of the plant, and the user can interact with the MR genie for fun, increasing the user's sense of interactive experience.

There is a compost bin in the front belly of the robot, in which food waste and delivery boxes can be put to compost. The compost bin can be taken out for cleaning. In addition to this, artificial lighting is used to meet the needs of plants. And provide dark mode, the lights on both sides to give the dark environment to provide a weak light, with a sense of technological intelligence. The rollers can be opened for easy movement. The four hole chambers provided can grow four different plants at the same time, and the open space around allows the plants to grow freely (see Fig. 5).

To reflect the needs of the plant in real time, the interface is designed with cute expressions to interact with the child. The primary interface shows three kinds of expressions under different conditions: normal state (smiling), abnormal state (crying) and feedback state (blinking) to reflect the plant state. When the expression is abnormal state, click

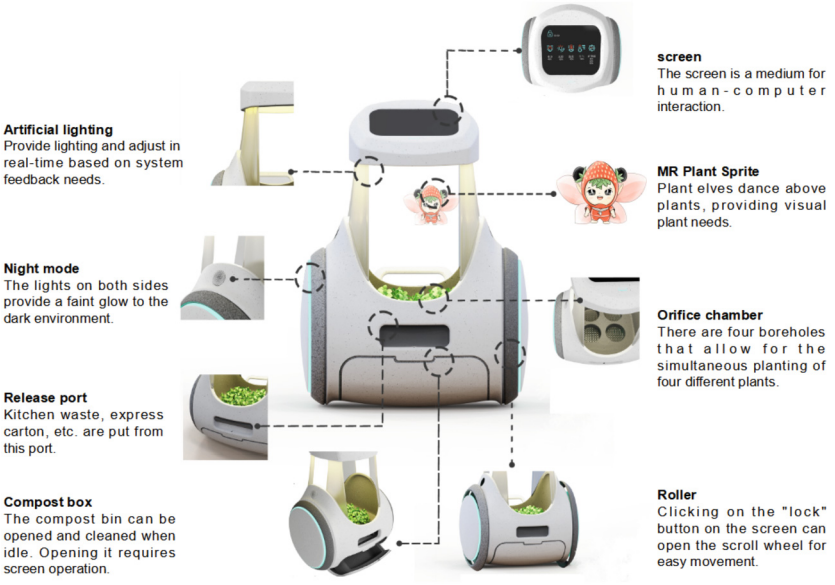

Fig. 5. Functional Structure.

to enter the second-level interface to show the cause of plant abnormality (including moisture, humidity, temperature, air, minerals, etc.). Select the abnormal item to click to enter the tertiary interface, which shows the relevant information of the four pore chambers, so that users can make precise adjustment conveniently (see Fig. 6). There is a child lock in the first level interface to prevent children from accidentally opening the compost bin.

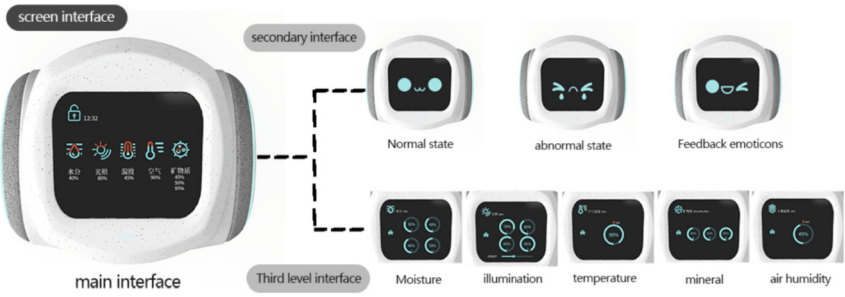

Fig. 6. Display of some user-interface. (Color figure online)

Simple and modern shape, smooth lines and one-piece appearance with a thin blue light band are in line with the home of the future technology. In terms of color scheme, the colorless black, white and gray is used, which is suitable for various home environments and gives a clean and tidy feeling. In terms of material, the white body is flame retardant ABS material, composting and watering parts are made by two-color injection. The blue

part is LED ambient light strip, showing a sense of future technology. Four pieces of frosted glass cover are connected in the middle of the product to ensure that the plants are allowed to grow naturally while somewhat reducing the impact of light on users' eyes.

5.1 Using Crowd Analysis

The design is aimed at children and people at home, and the product category is intelligent home robots. Through interviews with the target audience, we drew an empathy map from the four directions of "see", "think", "think" and "do". The empathy map was created to summarize and vote on some pain points of users (see Fig. 7).

Fig. 7. Empathy map of primary and middle school students living at home.

5.2 Demand Level Design Positioning

Emphasis on the process of human-computer interaction and meeting the value of self-actualization are the biggest needs of this product. Since the target population involves children, safety is also very important. The focus of the design is not on the high yield of the plant, but on the experience of the use process, so the physiological needs are placed in a less important position (see Fig. 8).

5.3 Scientific Carrier

Virtual reality technology is a new type of human-computer interaction developed in recent years, which can immerse people in a computer-generated virtual world. Ting Qiu et al. proposed to apply VR technology to planting design and integrate it into virtual simulation experimental teaching to break the limitations of design teaching and

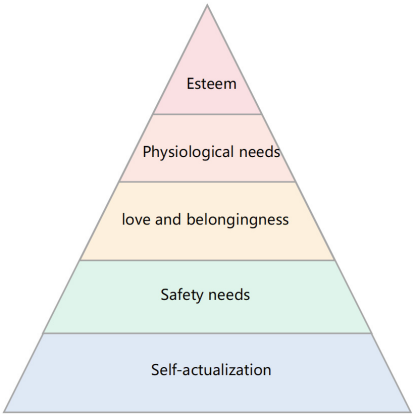

Fig. 8. Analysis of the demand for "SHUBAN".

apply virtual simulation technology to solve traditional teaching challenges [29]. MR technology, as a further development of VR and AR technology, can also be integrated into experimental teaching.

Mixed Reality (MR) is a type of digital perception technology that uses digital means to capture, regenerate, or synthesize various sensory inputs from the external world to achieve an immersive sense of immersion. It is able to establish interaction between the virtual world and the real world, to form a hybrid world in which the virtual and the real interact [30]. As MR technology is widely used, the technology is becoming more and more mature. Currently, MR technology is being explored and used in the fields of education, medical care, games, and sports [31]. Through MR technology, the audience is fully immersed in the virtual space, and some real feelings are induced by the virtual space. These experiences are real existences for human sensory experiences, but these objects are indeed fictional objects, thus blurring the boundary between virtual and reality [32].

Through MR technology, the "SHUBAN" projects the plant genie, and through the detection of soil, the plant genie's demeanor shows the state of the plant. For example, if the plant is short of water, the plant genie will show a thirsty demeanor (see Fig. 9).

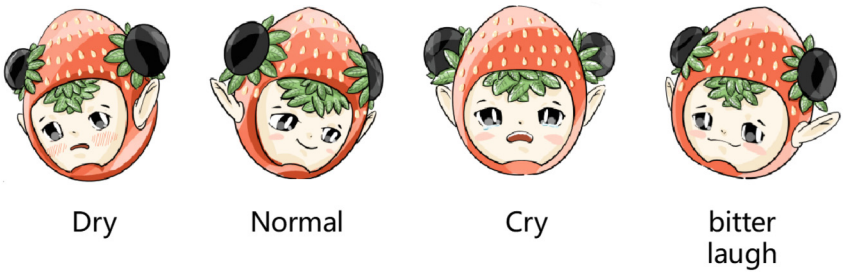

Fig. 9. The different demeanor of plant elves.

Jia Zixi et al. realized the control of inverted pendulum and robotic arm system in a virtual environment based on the virtual experiment system of MR technology [33], and the control of other virtual objects realized by MR technology provides practical experience for the application of MR in intelligent home growing robots. To meet the user's immersive home growing experience, the application of MR technology to intelligent home growing robots has some feasibility.

5.4 Explicit and Implicit Interaction Methods

The human-computer interaction of "SHUBAN" is mainly between the user and the plant sprite, which is considered as the main interaction. Some of the interactions that systematically regulate the needs of plants, as well as the tedious, simple and uninteresting interactions, are regarded as implicit interactions. The following Table 1 gives the explicit and implicit interactions of the "SHUBAN".

Table 1. Explicit and implicit interaction of "SHUBAN".

Explicit Interaction	Implicit Interaction
Robot expression interaction	Automatically turn on night mode at night
Delivery port switch	Real-time light adjustment
Compost bin switch	Automatic locking
Plant Genie	Automatic water storage
Plant Genie Interaction	
Roller switch	

The use of explicit and implicit interactions together in the design process can improve the human-computer interaction of core functions. More able to reflect the characteristics of the product, overly complex interactions may lead to misuse of product features.

5.5 User Experience

Since the "SHUBAN" did not actually land, a brief description plus interviews were conducted in the user testing session. The three aspects of communication were focused on basic user information, user needs, living conditions, and user satisfaction, respectively. Users had a high degree of expectation, and the results of the interviews are as follows (see Fig. 10).

Daily vegetable sources:
- Purchased at school vegetable market.
- Small onions and lettuce grown on the balcony by the elderly.
- Purchased at supermarkets.

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Age: 38years
Gender: female
Career: teacher
Life Situation: love life, living in the big city
Family Situation: has two children.

User Needs:
- Children to be able to eat green vegetables.
- Adding fun to life.
- To be able to interact with children.
- Educational programs to help children with productive work.

Satisfaction	0	1	2
Green Vegetables		✔	
Life Fun			✔
Interactive Communication with Children			✔
Product Novelty			✔

Fig. 10. User testing and scoring table.

6 Conclusion

This paper presents a product innovation design idea based on the interrelationship between science and design. Based on the literature review, this paper first summarizes the definitions of science and design and briefly describes the difference, connection, development, and application between the science and design. Next, the interrelationship between science and design in product design is summarized. Based on this, the design of product innovation ideas is proposed. Finally, a design case is used for validation and evaluation. Applying MR technology in intelligent home growing robots to achieve more interesting, human-machine interactive, and intimate product design. With the development of AI, it also makes the design of some concepts possible.

As demonstrated in this paper, the designer's grasp of science involves many aspects of design research. Considering that the idea is not explicitly targeted, future research can use the idea as a guide for different design themes, already for further exploration. In order to bring inspiration to similar design research in terms of innovative approaches and applied practices.

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