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User Research–Based Design Strategy for an Electric Water Heater and Its Application

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Abstract. To improve the performance of electric water heaters and innovate various product categories, this study primarily conducted user research and obtained data pertaining to the physiological and psychological characteristics, living habits, and user requirements of the target population as the starting point. Political, economic, sociocultural, and technological analysis, market analysis, household surveys, quantitative questionnaire surveys, and market visits were conducted to obtain the data for exploring the different user needs, integrating the needs of various users, conducting importance assessments of the needs, and developing design strategies for the electric water heaters. An industry breakthrough should be obtained by using the user experience–level data and by proposing new design strategies and corresponding design solutions.

1. Introduction

It has been increasingly noted that design of electric water heaters lack innovations. As the market demand for electric water heaters steadily increases, the new demands of Chinese families pertaining to water heaters and the user experience should be determined and improved, respectively. User-centered research, also known as people-oriented research, can help identify the target users of a product and accurately determine user demand. By conducting a qualitative analysis of user needs and the competitive environment, the precise status of a product in the early stage of development can be ascertained, the efficiency of the product upgrade process improved, and the product designed so as to achieve market success in the future.

2. Current state of the research in electric water heater design

On the basis of the type of energy consumed, water heaters are mainly divided into four types: electric-, solar-, gas-, and air-powered water heaters. Because electric water heaters have low installation costs and no regional limits and are eco-friendly and cost-effective, they have a large market share in China. However, in recent years, electric water heaters have been viewed as disadvantageous because of fundamental problems such as a low heating rate, less hot-water output, inconsistent water temperature control, and irregular water supply.

The use of clean energy is currently trending, and there has been a considerable increase in studies



pertaining to air- and solar-powered water heaters. A linear analysis of water heater studies conducted from 1998 to 2014 indicates an uptrend in the number of solar- and air-powered water heater studies, whereas the number of studies pertaining to the electric water heater has exhibited a descending trend (Figure 1). Zhiqiang (2016) proposed a method for improving the water-storage-type electric water heater and designed a smart electric water heater based on a single-chip microcomputer control system for superior and safe operation. Lei (2017) conducted a correlation analysis on the factors affecting customer satisfaction of electric water heater installations and proposed methods and means to improve the service satisfaction in the industry of electric water heaters. Nel (2016) conducted a nationwide online survey in South Africa to evaluate the awareness of energy conservation measures with respect to electric water heaters and the key factors affecting behavioral willingness. Kapsalis (2018) proposed an optimization algorithm for exploring how to operate the electric water heater under dynamic electricity pricing. The main area of concern for existing studies has been the improvement of the energy efficiency, availability, and quality of installation services of products. However, to continuously upgrade product consumption, the homogenization of products in the electric water heater industry is crucial. We must understand the new requirements of Chinese households with respect to obtaining high-quality hot water and should meet their key requirements to improve user experience. This study proposes a breakthrough design innovation strategy for electric water heaters and presents the corresponding design solutions.

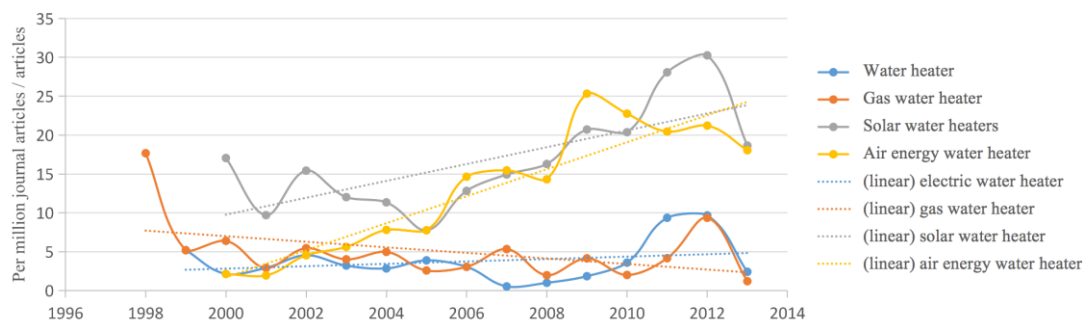


Figure 1. Linear analysis of water heater studies from 1998 to 2014
(Source: Wanfang Data, China National Knowledge Infrastructure)

3. Development of user research plans

The primary goal of this study was to identify a development direction for the design and technological innovation of electric water heaters, determine a road map for product technology development, find data and supportive logical points for product promotion and sales, improve the customer experience before purchase, enhance the sales and after-sales service experience, and establish a complete user requirement research system and related database. The secondary targets of this study were to determine the unmet requirements and potential problems associated with using electric water heaters and “accurately convert them into tangible as products or services based on their demand.

The research was divided into six phases:

(1) Information and data collection and analysis: Political, economic, sociocultural, and technological (PEST) analysis was conducted to determine comprehensive interventions at the policy level for sociocultural and technological development in China in terms of factors such as economic operation, changes in the population structure and culture. This study presents industry-related keywords as the core direction of the user research and the position of the target users.

(2) Development of the research plan: Using network information analysis and design, the “investment test questionnaire” was presented and demonstrated, and the household survey plan was formulated according to the demonstration results.

(3) Household observation: The “Daily Bathing Water Record Questionnaire” was issued during the initial 10 days. Then, the users’ bathing recordings were obtained and analyzed, and the core

questions of the users' bathing life were explored by conducting in-depth interviews.

(4) Market visit: Interviews with sales staff and installers were conducted to understand the construction of the end user experience supply chain.

(5) Questionnaire: The users' pain points were refined, and then, qualitative research was conducted using the results of the quantitative questionnaire to verify the conclusions of the users' pain points. Finally, methods to solve the users' pain points and meet user requirements were developed.

(6) Conclusion Integration: According to the previous five phases, this step involved output product innovation development planning and product design strategy development.

4. Analysis of user requirements

4.1 Primary study

In the early stage of network information and data collection, we used PEST analysis-based research methods to collect information data from policies, the economy, the society, and technology and to summarize the information and attract social attention. A number of keywords were extracted and classified, as shown in Table 1.

Table 1. Primary perspective research keyword integration

policy economic situation fertility anticorrosion financial policy real estate subsidy policy event change accident urban/rural engineering	health safety quality maintenance	e-commerce industry disadvantage internet marketing solution	service industry status marketing GDP	heating method energy conservation efficiency multimode combination multienergy combination heat recovery surroundings environmental protection energy
	intelligent comfortable network control cloud/Internet of things intelligent control cross-border additional features	installation appearance		

On the basis of industrial attributes, five essential social concern-related keywords were extracted from the aforementioned keywords:

(1) Environmental protection and energy conservation: Although numerous energy-conservation studies exist, research attention has declined in the recent past. The number of dual theme and multiple theme studies has begun to increase, and studies on energy conservation and environmental protection have been stagnant as researchers have shifted in other study directions.

(2) Intelligent water heaters: The research attention on developing intelligent water heaters has been increasing at a steady pace. However, the existing technology is unable to meet customer expectations. Thus, the development process for creating a real intelligent water heater requires ongoing research.

(3) Health: In recent years, the emerging "keep healthy" selling point has received popular recognition.

(4) Installation: Installation is an inevitable process after purchasing and requires more attention.

(5) Environment and policies: Factors such as the economic situation of the country, real estate factors, and changes in fertility policies influence the industry. Companies have to seriously consider how to adapt to the environment and policies.

4.2 User research

In the user selection stage, we considered that the product is oriented toward the mass market. Because it caters to a high number of users, user categorization was conducted on the basis of three factors: city,

family structure, and brand of heater. The cities were divided into Central China, East China, and South China. The following cities were selected for household assessment: Shenyang, Beijing, Changzhi, Nanjing, Guiyang, and Fuzhou. The family structure was divided into four categories: direct family, couple family, standard nuclear family, and single-person households. The mainstream brands of water heaters such as AO Smith, Wanhe, Midea, Haier, Wanjiale, Ariston, and Siemens were included. Eventually, the researchers recruited 80 households to record their life scenes and product usage process.

Here, Shenyang was considered an example. On the basis of the information regarding urban planning, population structure, income level, water quality, and energy cost in Shenyang (Table 2) and the full coverage principle of the three levels of city, family structure, and brand, ten households were selected for household observation. Among them, the questions in the user interview questionnaire pertained to “object,” “person,” and “environment” throughout the time before purchase, during usage, and after sales service processes. Recordings such as videos, photographs, and questionnaires were used, as shown in Figure 2.

Table 2. Overview of the urban economy, water quality, and energy cost in Shenyang (2014)

Overview of Shenyang	In second-tier cities, the main urban area is completely urbanized and the population is aging.
Economy	House price: more than 7,000 yuan/m ² ; per capita income: 2,500 yuan, general consumption level
Water quality	Water quality is poor.
Energy price	Natural gas price: 3.30 yuan/m ³ ; electricity price: 0.50 yuan/kWh



Figure 2. Home research video data finishing (operation section excerpt)

The aforementioned household observations, interviews, and questionnaires yielded a large amount of data. The demand data collected by conducting household research were optimized (Table 3), and the Kano model was applied. To effectively draw accurate conclusions, the analysis process was divided into five steps: the model integrates the demand, evaluates the importance of the demand, uses the quantitative data obtained from the questionnaires to conduct demand filtering, and finally optimizes the project output (Figure 3). After the demand filtering is completed, the data is sorted, as presented in Table 4, on the basis of three stages—before purchase, during usage, and after sales service.

Table 3. Household research data optimization (operational problem excerpt)

Operational problems	1. Generally, the function of the electric water heater control panel will not be operated.
	2. The power switch of the outlet is pressed directly to start the machine without the operation panel process.
	3. The installation height of the water heater is within the users' controllable range, and the remote control was ineffective.
	4. For Beijing, a 24-hour boot state was observed in which only the mixing valve is used to adjust the water temperature.
	1. Users need to know the amount of hot water.
	2. The user test time was approximately 10–15 s on average, and the test time for a

	woman was slightly longer than 30 s.
	3. The user mixing valve adjusts the appropriate water temperature on the basis of the body temperature and repeats the operation approximately twice.
	2. The user turns off the mixing valve to use a shower gel while bathing (insufficient water or water wastage).
	2. The user turns off the mixing valve and opens the valve again in the middle. The water temperature is unstable and thus a user can be burned easily.
	3. The user uses a mouthwash while bathing.
	4. Women do not understand the function of the water heater.
	1. Most users are in the state of rest while bathing and adjust their position.
	2. There is no awareness pertaining to turning off the power of the water heater while bathing.
	3. After the bath is complete, users does not change the position of the mixing valve.
	4. The center knob is very high; thus, the elderly could not adjust the electric water heater.
	5. When a child takes a shower, the shower head is removed, and the water pipe is placed vertically in the basin.
	1. It is difficult to adjust the water temperature by adjusting the mixing valve while washing.

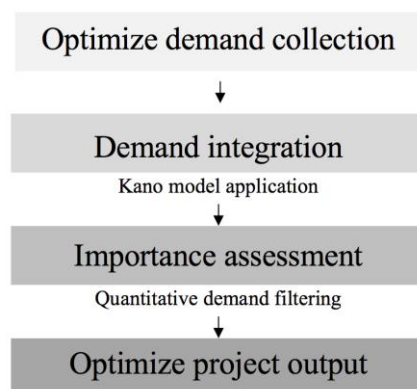


Figure 3. Process of demand mining, sorting, and exporting

Table 4. Demand export analysis

Before purchase	Users give special attention to the energy efficiency rating.	95%	Efficiency
	Users think that the water heater occupies a considerable amount of space.	85%	Installation space
	Users consider the hot water demand for the elderly, children, and women.	78%	Special population
	Users have concerns about the safety of electric heating.	85%	Safety
During	The water heater is kept powered on when the user is bathing.	60%	Usage habit intuitive operation
	Users conduct temperature adjustment.	93%	
	Users pay attention to the remaining amount of hot water and heating state of the water heater.	80%	
	The problem of water heater control is concentrated: the display		Prompt

	is not clear, the operation is not sensitive.		function
	The user indicates that the most expected function is product maintenance or water quality improvement.	50%	Water quality maintenance
	The user indicates that the most anticipated function is remote control.	42%	Remote control
	User does not receive maintenance activities and water change of the liner.	70%	
After sales	A user's dissatisfaction is concentrated in the slow response by the after-sales team and unclear charges.		After-sales specification

Analysis of the demand export results found that consumers pay attention to energy efficiency, installation space, water consumption and safety of special people before purchase; the user's pain points are easy to appear in the use habits, intuitive operation, residual water reminder function, water quality maintenance and Remote intelligent control of these nine aspects.

Judging from the data analysis results presented in Table 4, users' security concerns and usage habits conflict. Of the users, 85% worry about "electricity safety hazards" while using the appliance. The household observation results indicate that 60% of users unplug the heater before bathing (Figure 4). Because of this conflict, in-depth interviews were conducted, and it was determined that users are aware of the dangers of electricity because of their safety instinct. Moreover, some electricity leakage mishaps have circulated on the Internet. Thus, the impression that there is danger while using a "water heater" is deeply rooted in the hearts of the people. Two million results were obtained when the keyword "electric water heater leakage" was searched on Baidu. This demonstrated that electric water heater leakage accidents are not uncommon. Thus, users worry about safety while bathing when the electric water heater is in the on state, and this is not only a psychological factor.

The study of the functions of the six major brands of electric water heaters demonstrated that all major brands have improved their technology in terms of safety (Table 5 and Table 6). Most of the brands use the antielectricity technology of "three-pole break" and "anti-electric wall" for safety protection. The technical stage of the anti-electric wall cannot completely avoid the risk of electric leakage. The main causes of electric water heater leakage are the use of a machine for an extensive lifespan, failure of the protection technology due to the aging of the components, poor electrical environment, wrong connection of the circuit, aging of the wires, use of inferior sockets, and a user's wet hand touching the switch and plugs. The insecurity pertaining to the product safety causes a user to avoid use (Figure 4).



Figure 4. Some users plug in the power plug before bathing

Table 5. Technical finishing of the major mainstream electric water heater brand functions (1)

Brand	Heating energy efficiency	Protection safety	Liner technology	Energy saving	Healthy and clean	Intelligent humanization
Brand A	MAX rapid thermal capacity Separate double rod heating AES adaptive preheating	PS security system	Special protection liner	Medium temperature insulation AES adaptive energy saving system	IMM liner maintenance tips Patented liner cleaning technology Inner tank monitoring system	remote control One-click reservation Joint control shuttle system Real-time hot water tips
Brand B	3D+ rapid heating technology Rapid heat capacity Three-speed shift	Patented anti-electric wall Three-tiers power outages	Patented adamantane three-layer bile	Medium temperature insulation Inner insulation material (tight insulation layer)	Core magnesium rod	APP smart appointment Intelligent person washing play music
Brand C	E+4 times capacity increase heat Heating tube separation technology Water system - water cyclone technology Power - 3000W high power	M-SAFETY double earth leakage protection	"Blue diamond" liner	Thick insulation Peak Valley Nightingale Medium temperature insulation	Tech Water System One-button high temperature inhibition High purity activated carbon filter water core	remote control One-click reservation Washing Smart panel
Brand D	"Double engine" rapid heating technology Rapid heat capacity Submersible heating rod	Patented anti-electric wall Three-tiers power outages Hydroelectric separation	Three-layer "submersible tank" liner	Medium temperature insulation Inner insulation material (full latitude lock heat technology)	Fresh ion technology High purity magnesium rod fresh water	Smart butler function Schedule multiple timed heating
Brand E	Power - 3000W high power High nickel stainless steel heating tube Rapid heat capacity X4 Water system low mixing technology	Third generation double shield protection (anti-electric wall + three-tiers power outages)	Three-layer blue glazed adamantane liner	Liner insulation material - thickened energy foam layer Night energy saving	Extended magnesium rod	WIFI cloud intelligent interconnection system Remaining hot water display, reservation
Brand F	Titanium heating tube, increasing area Water system low mixing technology	Break gate Ten heavy security	Titanium liner	Intelligent - automatic energy saving	Silver net antibacterial	Intelligent WIFI Customized APP
Brand G	Navi Instant Heat Double heat expansion	ELCB Three-tiers power outages Hydroelectric separation heating tube	5A plasma liner	King Kong HoldTM overall foaming Smart Valley 5 day and night insulation	Easy to clean water function Smart liner maintenance tips	NAVI Reminiscent of rigorous intelligent tracking Smart booking water

Table 6. Technical finishing of the major mainstream electric water heater brand functions (2)

Brand	Heating energy efficiency	Protection safety	Liner technology	Energy saving	Healthy and clean	Intelligent humanization
Brand A	MAX rapid thermal capacity Separate double rod heating AES adaptive preheating	PS security system	Special protection liner	Medium temperature insulation AES adaptive energy saving system	IMM liner maintenance tips Patented liner cleaning technology Inner tank monitoring system	remote control One-click reservation Joint control shuttle system Real-time hot water tips
Brand B	3D+ rapid heating technology Rapid heat capacity Three-speed shift	Anti-electric wall Three-tiers power outages	Patented adamantane three-layer bile	Medium temperature insulation Inner insulation material (tight insulation layer)	Core magnesium rod	APP smart appointment Intelligent person washing play music
Brand C	E+4 times capacity increase heat Heating tube separation technology Water system - water cyclone technology Power - 3000W high power	M-SAFETY double earth leakage protection	"Blue diamond" liner	Thick insulation Peak Valley Nightingale Medium temperature insulation	Tech Water System One-button high temperature inhibition High purity activated carbon filter water core	remote control One-click reservation Washing Smart panel
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Brand E	Power - 3000W high power High nickel stainless steel heating tube Rapid heat capacity X4 Water system low mixing technology	Double protection Third generation double shield protection (anti-electric wall + three-tiers power outages)	Three-layer blue glazed adamantane liner	Liner insulation material - thickened energy foam layer Night energy saving	Extended magnesium rod	WIFI cloud intelligent interconnection system Remaining hot water display, reservation
Brand F	Titanium heating tube, increasing area Water system low mixing technology	Break gate Ten heavy security	Titanium liner	Intelligent - automatic energy saving	Silver net antibacterial	Intelligent WIFI Customized APP
Brand G	Navi Instant Heat Double heat expansion	ELCB Three-tiers power outages Hydroelectric separation heating tube	5A plasma liner	King Kong HoldTM overall foaming Smart Valley 5 day and night insulation	Easy to clean water function Smart liner maintenance tips	NAVI Reminiscent of rigorous intelligent tracking Smart booking water

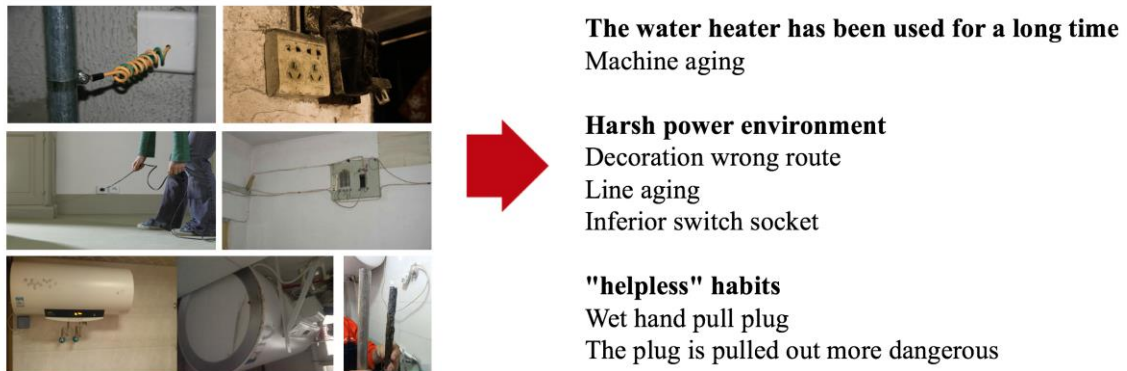


Figure 5. Reasons for electric water heater leakage

5. Redefine electric water heaters

In response to the users' security concerns, we redefined the electric water heater with respect to the function "shower with automatic power cut-out" and proposed a new design strategy in terms of the product, product design, functional technology improvement, user experience improvement, and promotion plan.

(1) Appearance design of the product

The control panels of common electric water heaters in the market are super layered and very rigid; thus, they cannot give people a visual sense of security. Based on the first level of Donald's three levels of emotional design, the visceral level, that is, products that produce the most direct primary emotions by the user, are instinctively stimulated by perceptual experience. The visceral level is also the level of attraction of the product's shape. In this study, the electric water heater control panel and the water deflector are combined, and the user is given a visual hint of the usage safety through a smooth and rounded curve and a soft and warm color (Figure 6).

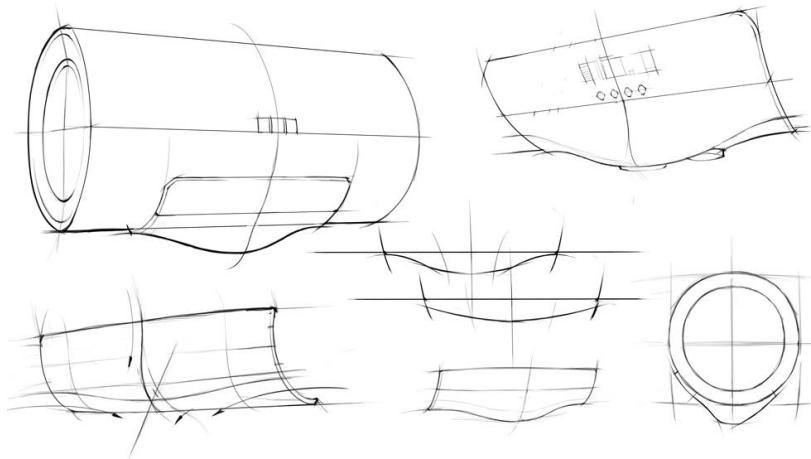


Figure 6. Design sketch

(2) Function and technology innovation strategy

This study proposed a "no electric washing" technology. When the electric water heater water valve is opened, the water flow causes the built-in sensor core to detect the signal, and the signal is transmitted to the broken core through the circuit board to realize the hot, ground, and neutral lines. All the lines are disconnected so that the whole water heater is in a state of no electricity, thus ensuring safety during a bath. After the user has finished bathing, the water heater is automatically reset after 5 min of closing the water valve.

(3) User experience design

To enable consumers to perceive that the product is in the safety state, when the water valve is opened, the display screen automatically turns black. The black screen accurately conveys the message that there is “no electricity.” This innovation effectively eliminates user anxiety while taking a shower.

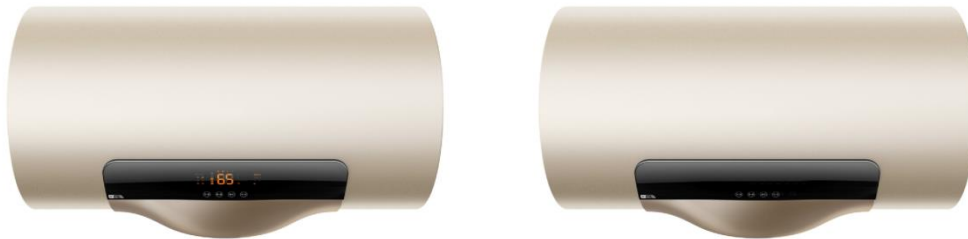


Figure 7. Design of the display interface based on the goal of eliminating user anxiety

(4) Developing product promotion plan

With the theme of “shower with automatic power cut-out,” we developed a promotion framework by communicating with consumers and understanding their acceptable price for the product (Figure 8). By using the “smart water heaters, triple safety guarantee” as a slogan and the selling point, we continuously promoted the product online and offline. Consumer awareness of the existence of a safe water heater was achieved, and the advertising strategy strengthened the recognition of the product and redefined safe bathing. Therefore, the product secured a leading position in the market among electric water heaters.

Industry theme	Shower with automatic power cut-out		
Category value claim	Respect every life and lead the upgrade of electric water heater safety technology		
Representative series	S6 series products		
Product identity	S6 “Shower with automatic power cut-out” + 6 Safty functions		
Promotion theme	Without electricity, With safty		
Consumer pain points	Worried about leakage during bathing, psychological fear		
Reason	The decoration is connected to the wrong line, the line is aging, the inferior switch socket, the wet hand plug switch, the socket is easy to be pulled out, and the machine itself is aging.		
First-level selling point	Bathing without electricity		
First-level communication	Intelligent core technology, Triple security		
Core technical support	iSense sensor	iCut power off chip	iPlug switch chip
Communication language	Inlet induction transmission power off signal	The whole machine is powered off during bathing	Automatically reset power after stopping water for 5 minutes
Secondary selling point	Anti-electric wall	WI-FI reservation hot water	Patented antibacterial liner
Three-level selling point	Waterproof touch screen, fluid safety shape, anti-corrosion moisture-proof shell		

Figure 8. Product promotion framework

6. Conclusion

This study adopted user research as the core methodology to investigate solutions for electric water heater innovation breakthroughs from the perspective of user experience design. By analyzing the potential requirements of users in depth, it was found that some users were concerned about safety while using an electric water heater and removed the electric water heater plug from the socket before

bathing. An in-depth study of this behavior revealed that a power cut-off function was required when users used the product. Thus, a product innovation design strategy was developed to eliminate user safety concerns and improve user experience, and a promotion framework was constructed. Guidelines were obtained to provide a reference for the electric water heater industry in terms of exploring product innovation.

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