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

Zhijian Liang¹, Yaqi Zheng¹, Ningchang Zhou²*, Shifeng Liu¹

¹East Innovation Industrial Design Co., Ltd., No.1, Yaogang Rd, Shunde District, Foshan, Guangdong, China
²South China Agricultural University, No.483, Wushan Rd, Tianhe Distric, Guangzhou, Guangdong, China
*Corresponding author’s e-mail: 93890290@qq.com

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 use 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). Zhiquiang (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.

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

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. |
| Operational problems | 2. The power switch of the outlet is pressed directly to start the machine without the operation panel process. |
| Operational problems | 3. The installation height of the water heater is within the users’ controllable range, and the remote control was ineffective. |
| Operational problems | 4. For Beijing, a 24-hour boot state was observed in which only the mixing valve is used to adjust the water temperature. |
| Operational problems | 1. Users need to know the amount of hot water. |
| Operational problems | 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.

![Diagram](image.png)

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.  

| User's dissatisfaction is concentrated in the slow response by the after-sales team and unclear charges. | After-sales specification |
| 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% |

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 technology | PS security system | Special protection line | Medium-temperature insulation AES adaptive energy-saving system | IMM linear maintenance tips | Remote control One-click reservation Joint control double system Real-time hot water tips |
| Brand B | 3D rapid heating technology Rapid heat capacity Three-speed shift | Patent anti-electric wall Three-sides power ranges | Patent anti-corrosion three-layer tank | Medium-temperature insulation liner insulation material (light insulation layer) | Core magnesium rod | APP smart appointment Intelligent person washing play music |
| Brand C | E-4 tons capacity increase heat heating tube separation technology Water system - water cycle technology Power - 3500W High power | MANSAFY double orchard leakage protection | "Blue diamond" liner | Thin wall insulation Peak Valley Nightly Medium-temperature insulation | Thin wall insulation 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 | Patent anti-electric wall Three-capsule power ranges Hydrodynamic separation | Three-layer "submersible tank" liner | Medium-temperature insulation liner insulation material (light insulation layer) | Fresh ion technology High purity magnesium rod Fresh water | Smart heating function Schedule multiple timed heating |
| Brand E | Power - 3500W High power High nickel stainless steel heating tube Rapid heat capacity N4 Water system - iron mixing technology | Third generation double orchard leakage protection Anti-electric wall three-layer power ranges | Three-layer "blue glass" adamas centine | Liner insulation material - thickened energy from layer Night energy saving | Extended magnesium rod | Wi-Fi cloud intelligent Instantaneous control Remaining hot water display, reservation |
| Brand F | Titanium heating tube, technology area Water system - iron mixing technology | Book gate Ten-hairy security Titanium liner | Intelligent - automatic energy saving | Silver antibacterial | Intelligent WiFi Customized APP |
| Brand G | Next Instant Heat Double heat expansion | ELCI Three-capsule power ranges Hydrodynamic separation heating tube | 5A plasma liner | King Kool 7FDM overall heating Smart Valley 5-day and night insulation | Easy to clean water function Smart liner maintenance tips | NAVI Reminiscence of vigorous intelligent washing 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 technology | PS security system | Special protection line | Medium-temperature insulation AES adaptive energy-saving system | IMM linear maintenance tips | Remote control One-click reservation Joint control double system Real-time hot water tips |
| Brand B | 3D rapid heating technology Rapid heat capacity Three-speed shift | Patent anti-electric wall Three-sides power ranges | Patent anti-corrosion three-layer tank | Medium-temperature insulation liner insulation material (light insulation layer) | Core magnesium rod | APP smart appointment Intelligent person washing play music |
| Brand C | E-4 tons capacity increase heat heating tube separation technology Water system - water cycle technology Power - 3500W High power | MANSAFY double orchard leakage protection | "Blue diamond" liner | Thin wall insulation Peak Valley Nightly Medium-temperature insulation | Thin wall insulation 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 | Patent anti-electric wall Three-capsule power ranges Hydrodynamic separation | Three-layer "submersible tank" liner | Medium-temperature insulation liner insulation material (light insulation layer) | Fresh ion technology High purity magnesium rod Fresh water | Smart heating function Schedule multiple timed heating |
| Brand E | Power - 3500W High power High nickel stainless steel heating tube Rapid heat capacity N4 Water system - iron mixing technology | Third generation double orchard leakage protection Anti-electric wall three-layer power ranges | Three-layer "blue glass" adamas centine | Liner insulation material - thickened energy from layer Night energy saving | Extended magnesium rod | Wi-Fi cloud intelligent Instantaneous control Remaining hot water display, reservation |
| Brand F | Titanium heating tube, technology area Water system - iron mixing technology | Book gate Ten-hairy security Titanium liner | Intelligent - automatic energy saving | Silver antibacterial | Intelligent WiFi Customized APP |
| Brand G | Next Instant Heat Double heat expansion | ELCI Three-capsule power ranges Hydrodynamic separation heating tube | 5A plasma liner | King Kool 7FDM overall heating Smart Valley 5-day and night insulation | Easy to clean water function Smart liner maintenance tips | NAVI Reminiscence of vigorous intelligent washing Smart booking water |
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).

(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.

![Display Interface Design](image)

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.

![Product Promotion Framework](image)

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.

Reference
[1] Cagan, J., Vogel, C.M. (2001) Creating Breakthrough Products: Innovation from Product Planning to Program Approval. FT Press, New Jersey.
[2] Tan, Z.Q., Yang, J.J., Lou, Z.B., Wei, C.J. (2016) Design of Intelligent Home Electric Water Heater Control System. Instrumentation Technology, 3: 1-4.
[3] Dong, L. (2017) Research on Customer Satisfaction of Electric Water Heater Installation Service Based on Structural Equation Model. Tianjin University of Finance and Economics.
[4] Nel, P., Booysen, M., Merwe, B.V. (2016) Energy Perceptions in South Africa: An analysis of behaviour and understanding of electric water heaters. Energy for Sustainable Development, 32: 62-70.
[5] Kapsalis, V., Hadellis, L. (2017) Optimal operation scheduling of electric water heaters under dynamic pricing. Sustainable Cities and Society, 31: 109-121.
[6] Joseph kim-keung ho, (2014) Formulation of a Systemic Pest Analysis for Strategic Analysis. European Academic Research, 5.
[7] Norman, D.A. (2005) Emotional Design: Why We Love (or Hate) Everyday Things. Basic Books, New York.
[8] Gu, R., Mu, B.N., Wang, G., Yang, Y.P., Li, K., Gu, Y.F. (2015) Analysis and Expression of Instinct, Behavior, Reflection in Emotional Design. Packaging Engineering, 36(16): 87-90.
[9] East Innovation Industrial Design Co., Ltd., (2018) Bathing Without Electricity. http://www.east-innovation.com/?p=11773.
[10] Yin, J.G., Wu, Z.J. (2012) Methods and Trends of Product Emotional Design. Journal of Hunan University, 16(1): 161-163.
[11] Zhang, L.H. (2006) Design Research Based on Cultural Anthropology. Art & Design, 2006(6): 14-15.
[12] Tang, L.T. (2006) Industrial Design Method. China Architecture & Building Press, Beijing.