The Design of a Garbage Classification APP based on the KJ-KANO Model and Gamification Collaborative Mechanism

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Abstract. This study aims to accurately identify and synergistically balance multi-stakeholder needs to enhance waste sorting efficiency and user engagement. Methodologically, an improved KJ method was adopted to construct a tripartite needs alignment framework, yielding a standardized requirement inventory. Based on KANO theory, a bidirectional questionnaire was administered to compute Better-Worse coefficients for need classification and prioritization, followed by the development of a gamified collaborative design mechanism to interconnect the three stakeholder groups and inform the APP design. The findings delineated the functional requirements of waste collectors, recycling merchants, and child users, which were subsequently integrated via a dynamic priority matrix and translated into design elements, culminating in a coherent design scheme that demonstrably improves sorting accuracy, accelerates recovery-reproduction workflows, and broadens public access to classification knowledge. The integrated KJ-KANO and gamification-based approach effectively curtails subjective design bias, enhances objectivity through the triangulation of needs clustering, classification, and systematic design, and facilitates dynamic need equilibrium via gamified collaboration—thereby enabling more efficient and precise multi-party coordination. Moreover, it offers a reusable methodological framework for stakeholder-oriented design and contributes meaningfully to the promotion of sustainable, green lifestyles.

Keywords: KJ method; KANO model; Four-quadrant model; Gamified collaborative design

1 Introduction

In recent years, China has vigorously promoted the implementation of domestic w aste classification, but the accuracy rate of waste sorting remains low, and progre ss has been uneven across different areas. Waste classification is characterized by repetitiveness, complexity, and intractability. At the current stage, urban and rura l residents still have relatively weak awareness of sorting waste correctly at the s ource.[1]The vast majority of waste still needs to be sorted manually. Therefore, it is very important to reduce waste at the source and cultivate the habit of correct disposal. Under the 'Community Little Masters' scheme promoted in Baoshan Di

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strict, Shanghai, children engage in public matters—including garbage sorting and hallway beautification—in the capacity of 'community stewards.' The egalitarian approach to dialogue transforms children from passive subjects of regulation into active contributors to community governance, thus fully tapping into their perceptiveness and fostering equitable exchanges across generational groups.[2]At the same time, building an information bridge between waste generators and recyclers can effectively avoid the dilemmas caused by information asymmetry, such as 'having waste that cannot be disposed of' or 'having no waste to process.' It also reduces intermediate steps, accelerates the flow of waste between buyers and sellers, closes the loop, and speeds up the circulation of the waste classification industry chain.[3]This research seeks to develop a standardized design framework that links waste collectors, secondary-material recyclers, and child participants as interdependent stakeholders. By doing so, it aims to enhance the efficiency and precision of recyclable waste recovery, improve overall recycling rates, lower disposal expenditures, and curtail the squandering of resources.

2 Analysis of the Characteristics of Existing Waste Classification Apps

Children possess strong behavioral influence and can drive families and communities to participate in environmental actions through the 'little hands holding big hands' effect. With the increasing prevalence of digital education, gamified educational software has gradually become integrated into children's daily lives. However, most existing educational waste-sorting apps or mini-programs currently on the market are limited to basic functions such as knowledge dissemination, category identification, and game-based challenges. Children's understanding largely remains at the theoretical level, lacking tangible hands-on experience and authentic behavioral feedback. There remains an urgent need in the market for waste-sorting applications that can effectively enhance user engagement and establish cross-group connections.

3 Research Methods

3.1 KJ Method and KANO Model

The "KJ Method," also referred to as the Affinity Diagram Technique, was pioneered by the Japanese scholar Jiro Kawakita in 1964. Employing a systematic procedure, this approach gathers functional requirements, transcribes them onto functional cards, and proceeds with classification and consolidation, thereby generating a comprehensive user needs inventory. To date, the KJ Method has found extensive application across various academic fields, including design studies.[4]

The KANO model, proposed by Japanese scholar Noriaki Kano, is a tool for user perception-based demand classification and priority evaluation. By quantitatively

analyzing user satisfaction with product functions, the model provides a scientific basis for design practice.[5]

Its core value lies in categorizing user needs into different levels—such as basic attributes, performance attributes, and delight attributes,[6] thereby guiding the optimal allocation of design resources.

The combination of KJ method and KANO model has been widely applied and verified in the field of product design.For example, in the elderly-friendly design of smart homes[8] and Health Management System Interface Design.[7]This combined method transforms user needs from vague fragments into structured priorities, providing quantitative basis for design. Cases prove the KJ-KANO framework handles complex group needs, laying methodological foundation for this study's tripartite collaborative demands.

3.2 Gamification Theory

The concept of gamification was originally introduced by Richard Bartle in his work The Gamification of Thought, with the core idea being 'to make non-game activities into games.[9]

Gamification thinking is a way of thinking that uses game elements and game design techniques in non-game contexts to design engaging experiences and drive users to take corresponding actions.[10]

Gamification theory, using points, badges, and leaderboards, motivates users and holds significant value in sustainable behavior and education. This study adopts it to build an incentive system for child users and explores its potential to connect consumers with recyclers and producers.

3.3 Application and Practical Significance of Innovation

Integrating KJ method, KANO model, and gamification theory, this study constructs a systematic design approach for multi-stakeholder contexts, shifting from "one-way satisfaction" to "multi-party balance." Standardized cards and a three-dimensional matrix uncover deeper needs and balance functional requirements, reducing costs while enhancing user participation. This methodology offers general guidance for collaborative and sustainable design research. See Figure 1 for the design process.

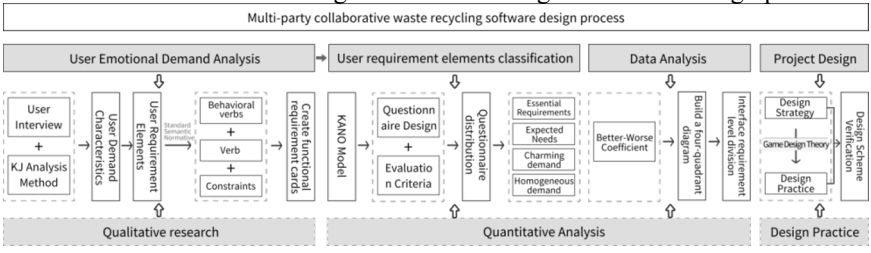


Fig. 1. Design flowchart

4 Garbage Recycling APP Function Requirement Analysis Based on KJ Method

4.1 Process Acquisition

The KJ method suits collecting functional requirements for recycling apps from waste collectors, recyclers, and child users, capturing diverse needs via systematic processes. This study employs purposive and snowball sampling—a non-probability approach—in both collection and survey phases to ensure sample representativeness.

4.2 Create Waste Recycling APP Feature Card and List of needs

72 participants—including recyclers, merchants, children, designers, engineers, and project staff—engaged in brainstorming, user storyboards, and in-depth interviews on "recycling APP functional requirements." The KJ method was applied to extract keywords, cluster semantics, and merge needs, removing redundancies and standardizing expressions. This yielded a functional card set across three dimensions: households, recyclers, and merchants. See Tables 1–3 for details.

Drawing on the functional requirement data reported in Tables 1–3, this study employed a hierarchical classification procedure to construct a structured requirement inventory system for a waste recycling APP. The system is organized around three target user groups: waste collectors, secondary-resource merchants, and families with children. The resulting requirement lists are presented in Figures 2–4.

5 Garbage Recycling APP Function Requirement Analysis Based on the KANO Model

In user-centered design, understanding and capturing user needs is essential.[11]Prioritizing user requirements as the fundamental impetus for design practice aligns with the human-centered design paradigm.[12]To accurately capture real needs of three user groups, KANO model quantifies functional indicators and prioritizes via Better-Worse coefficients.Using multi-source data collection, 72 respondents—covering recyclers, merchants, and child users—participated in brainstorming, storyboards, and interviews on "recycling APP requirements." The KANO model quantified functional attributes, established priorities, and captured explicit and latent perceptual needs, providing quantitative support for design decisions.

Table 1. "For consumer families, children and parents" garbage sorting APP function card

Number	Functional requirements items	Number	Functional requirements items
1	Using AR technology for waste classification identification	11	Limit the scope of personal information collection based on the principle of least necessary.
2	Based on the sorted waste, integrate the knowledge base	12	Based on keyword recognition to filter out illegal content
3	Record the total amount of waste disposed of and form a visual chart	13	Using natural language processing to respond to user voice commands

Number	Functional requirements items	Number	Functional requirements items
4	Feeding virtual pets with properly categorized waste as feed	14	Combine user location and trash bin capacity to guide garbage disposal locations
5	A knowledge challenge game with the content of sorting waste types	15	Based on waste item characteristics, push classification disposal suggestions
6	Unlock game achievements by completing specific tasks	16	Integrating carbon footprint data with social functions to build a green living community
7	Parents and children need to participate together to complete the family collaboration tasks.	17	Synchronize users' environmental data through cloud storage technology
8	Participate in environmental protection theme competitions as a family unit	18	According to the tasks completed by users, environmental protection behavior points are awarded.
9	Record family environmental protection behavior data through daily Check-in.	19	Users can redeem green goods with green points.
10	Limit user gaming time based on real-name authentication information	20	Providing environmental interactive experiences through multi-sensory simulation technology
21	Calculate regional environmental points based on user behavior data	22	Organize environmental protection theme activities on the specified date
23	Feedback on the bin being full sent via mobile phone	24	

Table 2. Garbage Sorting App Feature Cards for Waste Collectors

Number	Functional Requirements Items
1	Provide user question answering services through multi-platform access methods
2	Displaying feature tutorial on the user's current page
3	Collect waste disposal data through intelligent terminal devices
4	Based on sensor monitoring data, send trash bin status alerts
5	Monitor price fluctuations of recyclable materials through market data interfaces
6	Promote waste classification knowledge through various multimedia channels
7	Initiate waste recycling consultation through instant messaging function
8	According to the real-time positioning map, display the progress of the recycling worker's work.
9	Post work and life experiences through the community sharing section

Table 3. Garbage Sorting App Feature Card for Waste-Oriented Manufacturers

Number	Functional Requirements Items
1	Own a dedicated mall module for selling recycled eco-friendly products
2	Analyze and statistically summarize the sales data of recycled goods through transaction records
3	Analyze consumer preference data based on purchase behavior and feedback
4	Guide users through the operation process with a scenario-based interactive interface
5	Based on user cognitive logic to organize system operation units
6	Handle user after-sales requests through online instant messaging
7	Conducting a service quality survey via phone or questionnaire.
8	Users can exchange game points for physical or virtual goods.
9	Promote resource recycling knowledge through images, graphics, or videos

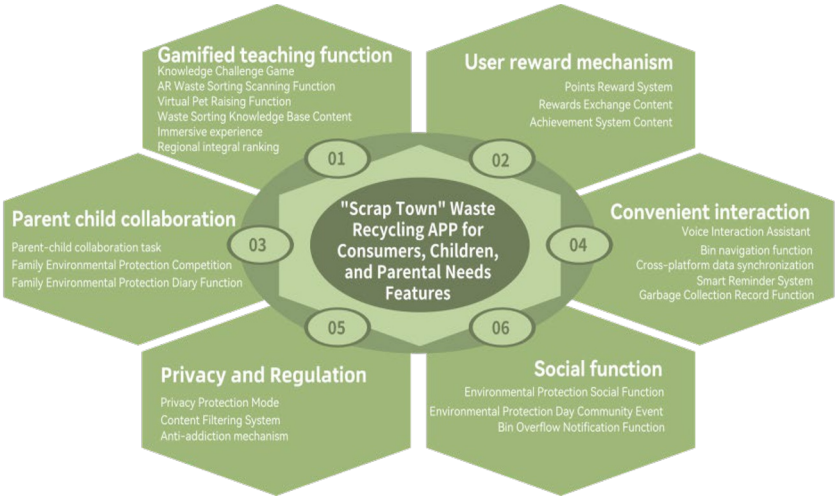


Fig. 2. Demand list of garbage sorting APP "for consumer family children and parents"

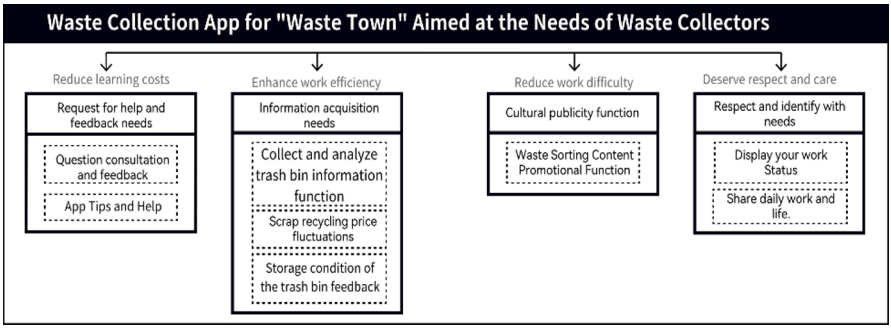


Fig. 3. Demand list of garbage sorting APP "for garbage collectors"

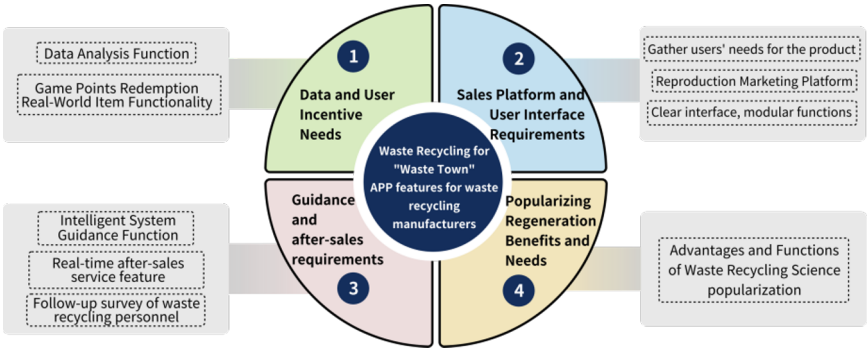


Fig. 4. Requirements list for a waste sorting APP "targeted at waste recycling businesses"

5.1 Design and Survey of the KANO Questionnaire

Based on KANO principles and the requirements list, a satisfaction questionnaire for APP needs was designed. Each item includes positive and negative questions with five-level options—"Satisfied" "Expected" "Neutral" "Tolerable" and "Unsatisfied"—as shown in Table 4.

Table 4. KANO model questionnaire format

User Requirements	Satisfied	Expected	Neutral	Tolerable	Unsatisfied
If the need is met, what is your evaluation	○	○	○	○	○
If the requirements are not met, what is your evaluation	○	○	○	○	○

5.2 KANO Collection and Organization of Questionnaires

A total of 130 valid questionnaires were collected, all of which made clear and non-duplicative selections regarding the positive and negative statements of the functional indicators. Based on the KANO model theory, the requirements were classified into five categories, with the specific classification results presented in Table 5.

Table 5. KANO evaluation form

Positive Question	Reverse Problem				
	Satisfied	Expected	Neutral	Tolerable	Unsatisfied
Satisfied	Q	A	A	A	O
Expected	R	I	I	I	M
Neutral	R	I	I	I	M
Tolerable	R	I	I	I	M
Unsatisfied	R	R	R	R	Q

5.3 "Consumer Family Children and Parents-oriented Waste Recycling APP Demand Results"

Needs of children and parents for an educational recycling APP were aggregated. Combined with KANO survey results, the Better-Worse coefficient was used to evaluate each function. Satisfaction (B) and dissatisfaction (W) coefficients were calculated via Formulas (1)-(2), as detailed in the figures.

$$B=(A+O)/(A+O+M+I) \tag{1}$$

$$W=-(O+M)/(A+O+M+I) \tag{2}$$

Based on aggregated needs of children and parents and KANO survey results, Better-Worse coefficients were calculated to analyze functional demand characteristics.

Twenty-three core requirements were identified and classified with coefficients, as shown in Table 6.

5.3.1 "Garbage Collection APP Requirements for Waste Recycling Personnel".

Based on recyclers' needs and KANO results, Better-Worse coefficients were calculated to analyze functional demand characteristics. Eight core requirements were identified and classified with coefficients, as shown in Table 7.

5.3.2 "Garbage Recycling APP Requirements for Waste Recycling Manufacturers".

Based on recyclers' needs and KANO results, Better-Worse coefficients were calculated to analyze functional demand characteristics. Nine core requirements for merchants were identified and classified with coefficients, as shown in Table 8.

6 Demand Integration Based on Better-Worse Coefficient

User needs are hierarchically distributed. Better-Worse plots show recyclers and merchants each have 2 basic, 1 performance, and 1 attractive need, while children/parents have 12 indifferent needs. Quadrant analysis optimized priorities, as shown in Figure 5.

Table 6. KANO attribute classification and Better Worse coefficient analysis of functional needs of family children and parent user groups

Categories	Number	Function	Proportion%						KANO Properties	B/%	W/%
			A	O	M	I	R	Q			
Game-based teaching requirements	1	Experience AR integration with reality	9.64	14.46	40.84	26.63	8.43	0	M	26.32%	-60.39%
	2	Offering a game format for knowledge challenge	10.84	21.69	29.64	19.76	18.07	0	M	39.70%	-62.65%
	3	Virtual pet companions for growth	10.84	15.66	6.02	53.01	14.46	0	I	30.98%	-25.35%
	4	Post-game knowledge organization and review	24.82	38.07	22.05	10.64	4.46	0	O	65.83%	-62.93%
	5	Immersive experience	7.23	19.28	9.82	52.67	9.64	1.37	I	31.56%	-28.69%
	6	Game Area Score Ranking	33.25	21.69	9.64	23.37	12.05	0	A	62.47%	-35.62%
Encourage users	1	Game points can be exchanged for in-game items.	10.84	15.66	7.23	55.42	10.84	0	I	29.73%	-25.68%
	2	Game Props exchange for physical rewards	4.82	18.07	34.64	28.01	14.46	0	M	26.76%	-61.62%

Categories	Number	Function	Proportion%						KANO Properties	B/%	W/%
			A	O	M	I	R	Q			
	3	Game Achievements and Medals	26.02	18.07	23.25	19.4	13.25	0	A	50.83%	-47.64%
Parent-child collaboration	1	Parent-child collaborative task	8.43	18.07	13.25	48.19	12.05	0	I	30.13%	-35.62%
	2	Family Environmental Protection Competition	6.02	19.28	7.23	50.6	16.87	0	I	30.43%	-31.89%
	3	Family Waste Sorting Log	13.25	18.07	3.61	50.6	14.46	0	I	36.62%	-25.35%
Convenient Interaction	1	Voice assistant helps solve problems	8.43	20.08	17.64	40.4	12.05	1.4	I	32.87%	-34.25%
	2	Bin Map and Navigation	10.84	39.64	7.23	26.63	15.66	0	O	59.85%	-55.57%
	3	Data Transfer	9.64	24.46	31.02	22.83	12.05	0	M	38.77%	-63.08%
	4	Intelligent Waste Sorting Reminder	7.23	31.69	27.23	21.81	12.05	0	O	44.25%	-66.98%
	5	Waste Sorting and Disposal Record	16.02	15.66	29.64	31.81	6.87	0	I	34.02%	-48.64%
Privacy and Regulation	1	Privacy Protection Mode	9.34	13.25	20.84	46.99	9.28	0	I	24.98%	-37.70%
	2	Screen filter	7.23	30.48	16.02	33.02	13.25	0	I	43.47%	-53.61%
	3	Anti-addiction mode	6.02	39.28	22.05	21.81	10.84	0	O	50.81%	-68.79%
Social and Collaboration	1	Environmental Protection Social Networking	10.84	16.87	6.02	55.42	10.84	0	I	31.08%	-25.68%
	2	Environmental Protection Day Community Activity Registration	14.46	18.07	4.82	50.6	12.05	0	I	36.99%	-26.03%
	3	Bin Overflow Notification	6.02	31.69	20.84	26.99	14.46	0	O	44.08%	-61.41%

Table 7. KANO attribute classification and Better Worse coefficient analysis of user group demand for garbage recycling personnel

Categories	Number	Function	Proportion%						KANO Properties	B/%	W/%
			A	O Properties	M	I	R	Q			
Seeking assistance and user feedback needs	1	Question consultation and feedback	12.5	13	6.25	50	15.63	2.63	I	31.19%	-23.55%
	2	App Tips and Help	30.09	21.68	6.25	29.29	10.95	1.75	A	59.29%	-31.99%
Information Acquisition Needs	1	Collect and analyze waste function	24.62	29.76	9.38	17.5	18.75	0	O	66.92%	-48.17%
	2	Scrap recycling price fluctuations	15.63	17.13	32.33	25	9.93	0	M	36.36%	-54.90%
	3	Report on garbage storage situation	18.75	12.5	23.03	37.5	8.23	0	M	34.05%	-38.71%

Cultural propaganda needs	1	Waste Sorting Promotion Function	16.25	15.63	9.38	48.03	8.75	1.97	I	34.93%	-27.41%
Respect and recognition needs	1	Display user work status	25	18.75	6.25	37.5	12.5	0	I	50.00%	-28.57%
	2	Share daily life and work	13.25	18.07	10.61	50.6	7.46	0	I	33.85%	-31.00%

Table 8. KANO attribute classification and Better Worse coefficient analysis of user group demand for waste recycling businesses

Categories	Number	Function	Proportion%						KANO Properties	B/%	W/%
			A	O	M	I	R	Q			
Data and User Incentive Needs	1	Data Analysis Function	18.75	12.5	5	50	12.5	1.25	I	36.23%	-20.29%
	2	Game points for real-world item exchange feature	20.12	10.63	36.25	26.25	4.25	2.5	M	32.98%	-50.27%
Sales platform and user interface must be required	1	Gather product development requirements	20.95	38.75	10.5	23.75	6.05	0	O	63.54%	-52.42%
	2	Reproduction Marketing Platform	22.5	16.5	34.25	25.5	1.25	0	M	39.49%	-51.39%
	3	Clear interface, modular functions	29.5	25.75	12.25	26.25	3.75	2.5	A	58.93%	-40.53%
Guidance and After-Sales Requirements	1	Intelligent System Guidance Function	18.75	25	6.25	31.25	18.75	0	I	58.93%	-51.39%
	2	After-sales service's even function	18.75	15	27.75	22.25	16.25	0	M	53.85%	-40.53%
	3	Follow-up survey of waste recycling personnel	16.25	15.63	9.38	48.03	8.75	1.97	I	40.30%	-38.46%
Reproduction advantage popular science demand	1	Advantages of Waste Recycling Science popularization	6.25	12.5	18.75	37.5	25	0	I	35.70%	-51.04%

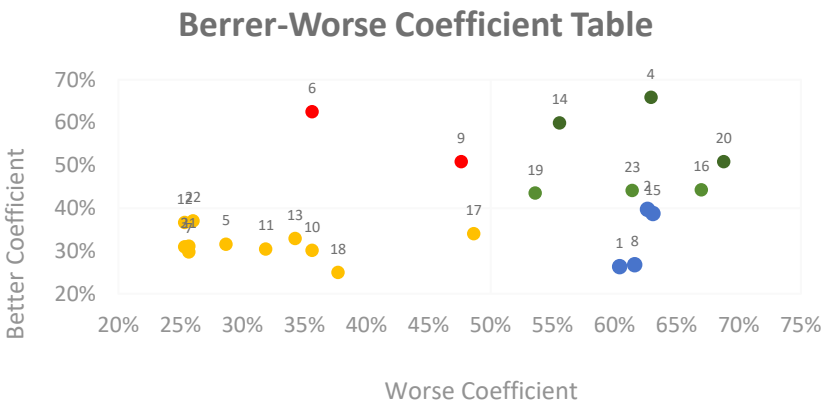


Fig. 5. Four quadrant model diagram of consumer families, children, and parents' demand for the functionality of the "garbage sorting APP"

7 Design Practice based on Design Strategy

The interactive experience of the APP directly shapes user perception and continuance behavior [12]. To address the heterogeneous requirements of three user groups, an integrated APP was developed, featuring a logo that employs recyclable materials to symbolize a green-home concept, with cartoon avatars facilitating identity selection. For children, a main interface (sorting game) and three sub-interfaces (quiz store, eco-mall, and scan module) were designed, wherein items sorted on a conveyor belt are archived in a collection library. The daily store offers quizzes and redemption services, allowing eco-coins to be exchanged for physical goods. A three-stage scanning procedure—barcode recognition, bin and item-type identification, and reward distribution—was implemented, with barcode usage capped at 10 times per week and overflow alerts transmitted to sanitation workers' terminals. See Figure 6 for details.

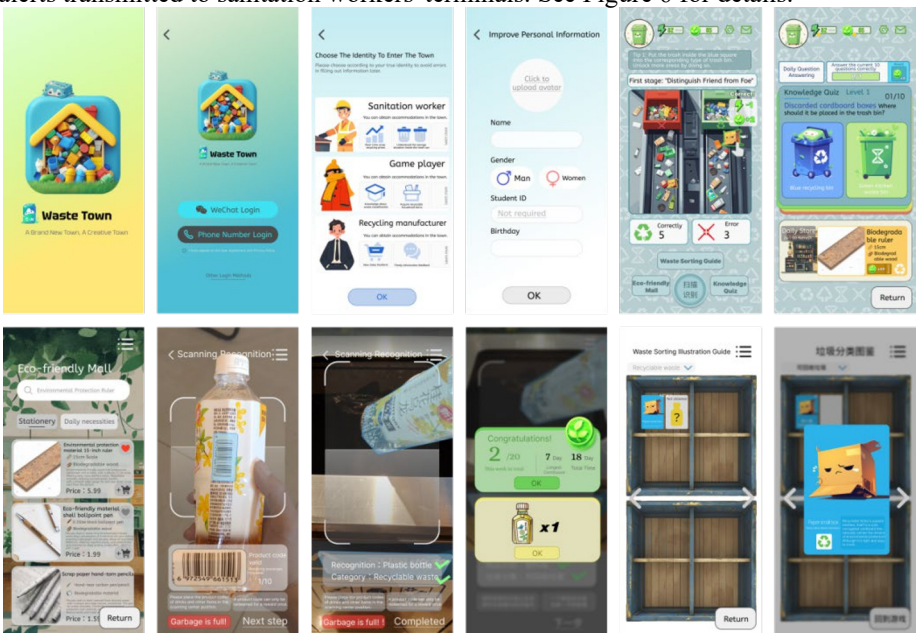


Fig. 6. Game-oriented interface design for children in consumer households

The recycler interface addresses "help feedback" and "information access" needs, with bottom navigation comprising price trends, waste sales, bin status, and personal modules. Price trends are displayed via bar charts showing daily recycling rates; the sales interface auto-calculates total amounts upon weight entry and synchronizes data with merchants to mitigate transaction disputes. Bin status leverages scanning to intelligently assess capacity, visualized via green-to-red gradients for fill levels, with one-click navigation to target bins. The personal module features sliding date queries (horizontal bar charts for multi-category comparison) and a floating voice assistant for real-time Q&A. See Figure 7 for details.



Fig. 7. Functional interface design for garbage collection personnel

The recycler merchant interface addresses "data incentives," "sales platform," and "after-sales guidance." The store adopts a square layout; clicking "Add" navigates to a product listing page (vertically arranged: image, name, description, tags). The "point-exchange" tag option synchronizes participating items to children's daily store for redemption, with quantities determined by merchants. See Figure 8.

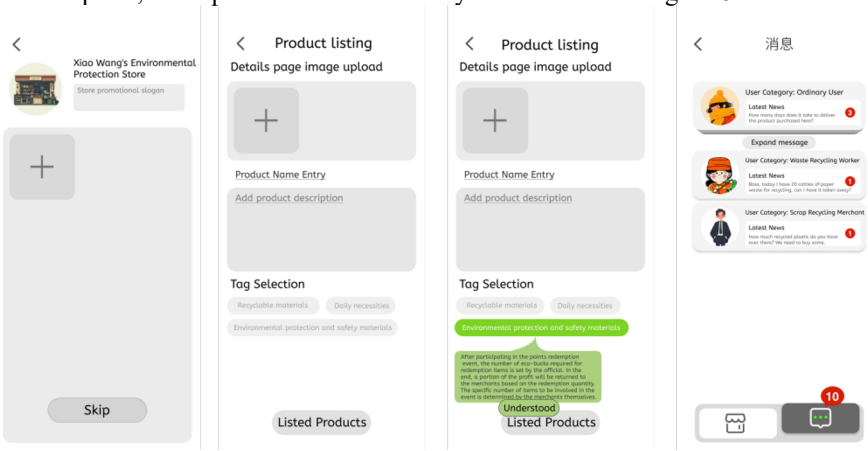


Fig. 8. Functional interface design for waste product recyclers

8 Summary

This study developed a KJ-KANO-GCD integrated model to transform tripartite user needs into design solutions, enhancing objectivity and synergy. Currently at the planning stage, future work will conduct usability testing (30 users, with SUS scores and interviews) and A/B testing to validate gamified collaboration mechanisms and functional effectiveness, thereby iterating the design and examining the methodology's value, forming a closed-loop evaluation.

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