Collaborative Design Practice in Computer Aided Industrial Design Process

Sheng Lin[1, a], Lu Li[2, b*]
[a] me_lins@ujn.edu.cn, [*] Corresponding author: [b] lilu@sdada.edu.cn

[1]University of Jinan, Jinan, China

[2]Shandong University of Art & Design, Jinan, China

Abstract—The multidisciplinary coupling of mechanics, electronics, automation and aesthetics will be the future of computer aided industrial design. This paper studies the application of collaborative design in the computer aided industrial design process, analyses the elements of collaborative design in design projects, optimises the computer aided industrial design process, integrates collaborative design into all stages and builds a computer aided industrial design framework applicable to collaborative design, which can effectively improve design efficiency and better complete high-quality design works. Finally, the CAID collaborative design process of an ecological monitoring vessel is combined with the actual industrial design project practice to verify the feasibility of the method. This research method can enhance designers' skills, knowledge and sensitivity, and improve their design thinking and problem-solving abilities.

Keywords-industrial design; collaborative design; participatory; design process

1 INTRODUCTION

Nowadays, the rapid development of industrial design discipline has brought many complex design problems. To solve such problems, we need to cross disciplinary boundaries and collaborate with multidisciplinary knowledge and methods to seek design innovation. In the practice of industrial design, the design process is improved, experts with different background knowledge are integrated through collaborative design, collaborative design capabilities are developed and collaborative design innovation is explored. This study constructs a collaborative design framework based on the computer-aided industrial design process and applies the theoretical results in practical industrial design projects, effectively improving the design process, improving design efficiency and design quality.

2 PARTICIPATORY COLLABORATIVE IN INDUSTRIAL DESIGN

2.1 Design collaborative

Industrial design is a design activity that applies a strategic problem-solving process to products, systems, services, and experiences. Collaborative design in industrial design is a knowledge-intensive activity that builds a conceptual design solution based on a shared vision and

ICICA 2022, December 02-04, Chongqing, People's Republic of China

DOI 10.4108/eai.2-12-2022.2327969

understanding. Collaborative design effectively enables the generation and transfer of effective knowledge in design projects.

Industrial design activities involve sociology, ergonomics, mechanical engineering, materials, psychology, aesthetics, color science and other disciplines. When solving design problems, it is necessary to comprehensively consider various design related elements and seek the optimal solution of design. Collaborative design is a participatory design method, which can quickly collect the views of professionals from different backgrounds and disciplines, and promote the formation of agreed solutions. The introduction of collaborative design in industrial design activities can effectively avoid various attribute defects of design schemes and improve the comprehensive design quality of products.

2.2 Multidisciplinary knowledge of collaborative design team

Collaborative design aims at specific design goals. More than two design subjects complete this design goal by using different knowledge backgrounds through the set information interaction and mutual collaboration mechanism. Collaborative design has the characteristics of multi-agent, collaboration, commonality and flexibility. Collaborative product design means the product design process in which both industrial design and engineering design are directly involved in product development activities [1]. Multi-subjectivity refers to mutually independent knowledge background experts, while collaboration refers to the construction of a design agency with common goals. Collaborative design can effectively integrate different disciplines to solve complex design problems.

3 INTRODUCTION OF COLLABORATIVE DESIGN IN INDUSTRIAL DESIGN PRACTICE PROCESS

In the industrial design practice, designers use market research to conduct detailed product information research for products with specific attributes, complete the construction of product feature information based on specific users, and dynamically use various design methods to carry out design around users' needs of material, function, emotional, aesthetic, etc. Industrial designers use design methods to collect product related knowledge information, analyze user data, rebuild new product knowledge data, derive design concepts, and finally integrate product attributes with objective and subjective data, and form conceptual industrial design.

With the involvement of external designers, projects can be effectively enhanced in terms of creation and design management [2]. The process of industrial design practice in conjunction with co-design expands the industrial designer's professional background knowledge and promotes the development of the designer's inspiration, insight and intuitive thinking skills. Through the absorption and digestion of design examples, we can understand design in a broader intellectual context, improving the designer's powers of observation, perception, imagination and exploration. This study builds a collaborative design system that includes designers and external designer resources, as well as knowledge resources for product development, as shown in Figure 1.

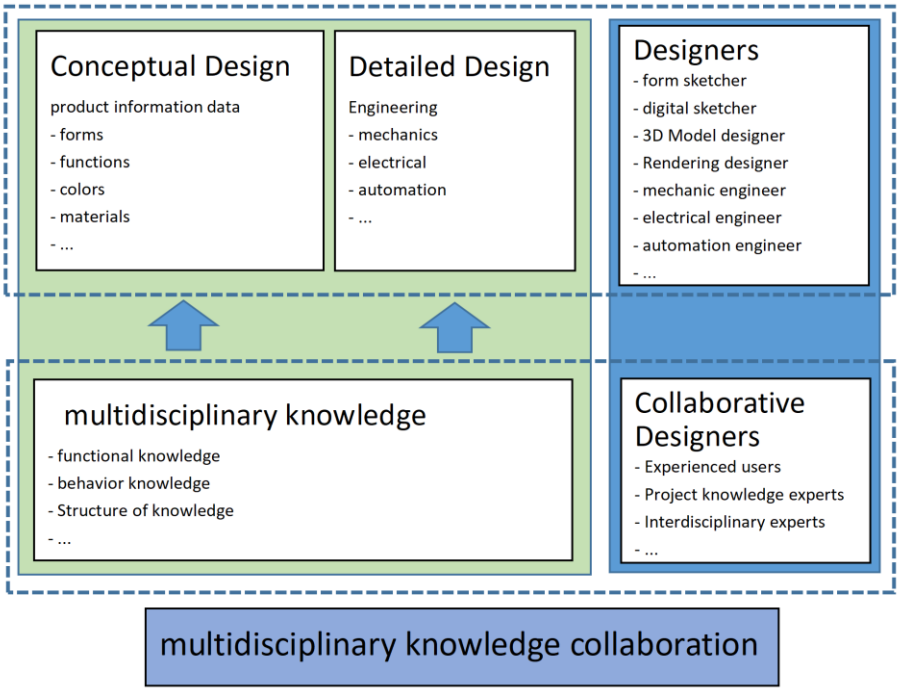

Figure 1 collaborative design system

3.1 Collaborative industrial design

The reasonable introduction of collaborative design in industrial design can use collaborative design methods differently in the design process according to the design goals. According to the different stages of the design, we should build a phased collaborative design goal and a group of experts with different knowledge backgrounds to plan the design activities. Collaborative design should establish correct time and process arrangements for participants and design teams, collect necessary knowledge elements for design activities, timely adjust sub objectives of industrial design according to the progress of the design process, especially design interference factors, and dynamically manage expert groups and designers [3].

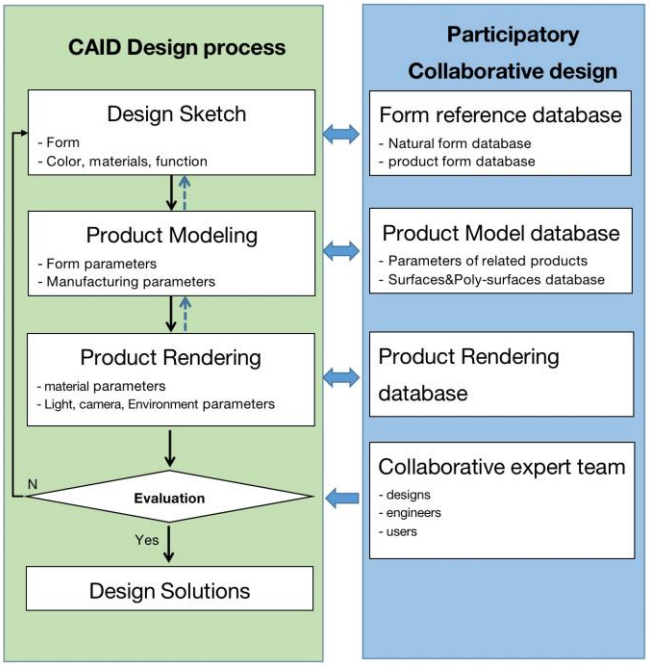

Figure 2 collaborative CAID process with reference design

As shown in Figure 2, building a CAID process that incorporates collaborative design practices can effectively organise and process the product information, environmental context, user experience and other elements of design, and tap into the conscious agency and subjective creativity generated in the interaction between the design subject and the object, thus effectively avoiding the negative effects of the dual mediating role in product design and the virtual nature of the design subject and design objectives.

3.2 Several stages of collaborative design in industrial design practice

Collaborative design combines the design process of dynamic design methods and strategies, pays attention to product attributes and user background attributes, deeply explores the elements of user experience from a multidisciplinary perspective, differentiates the strength and weakness of user needs, and develops design cognitive evolution ideas around the "product human environment" system. Collaborative design involves conceptual design stage, scheme design stage, and design expression stage in industrial design practice teaching. In the conceptual design stage, it involves product intention setting, design resource allocation, customization of project process, optimization of project objectives, etc; In the conceptual design stage, designers and participants need to come from different background knowledge fields, think about and reflect on product related attributes from their respective professional backgrounds, so as to explore the unknown context of product attributes; Deeply excavate the hidden knowledge related to the "product human environment" system, such as the product related attribute factors in human physiology, psychology, behavior and ideology, and transform it into an innovative product design concept with the help of conceptual expression in

product design[4]; In the scheme design stage, the designers of the collaborative design team jointly explore the phased sub design goals according to the project demands, develop and form the design ideas of the team, thus forming specific product design intentions, and show the design ideas through graphical methods; In the design expression stage, the achievements of the preceding stages are formed into product forms through design expression means such as sketches, renderings, models, animation, etc., to form a concrete product design.

4 DESIGN PRACTICE BASED ON COLLABORATIVE DESIGN

The promotion of design innovation ability has always been the core element of industrial design education. Nigel Cross summarized the core abilities of students majoring in industrial design as follows: the ability to solve problems not clearly defined; The ability to focus on strategies for solving problems; Design thinking ability of traceability and equivalence; Graphic and spatial expression ability. Building such capabilities requires interdisciplinary design collaboration. In the design practice, according to the different stages of the scheme development, the collaborative design is carried out reasonably by combining process optimization, time control and design method strategies. Industrial design aims at solving specific design problems, and in practice, it should dynamically decompose the goals to form a series of design sub goals. In different stages of design, the design process shall be reasonably and effectively promoted under the guidance of dynamic design sub goals and in coordination with different design resources. In the design practice teaching, it is better to guide and control the design cognition flexibly at different stages. In project time allocation, more time can be allocated in the design exploration stage as a key point, and multiple time nodes can be determined in each stage to control the design process, so as to improve the time efficiency of design progress.

In the design exploration stage, collaborative work can use graphical expression means to understand the user's background world, combine cultural exploration, scenario map, role analysis, story board and other design methods, focus on data collection and analysis of user experience, and deeply explore the product feature information that users expect, so as to create a design concept [5]. The integration of collaborative design can guide the design team to excavate the deep hidden knowledge in the user's background knowledge, which can often form more innovative design concepts. For example, in the course of product improvement design, using collaborative design, the team explores the customer experience history map of a specific product, which can better record the user's behavior, feelings, views and psychological activities when using the product. So as to effectively improve the user behavior in the actual use environment, and provide effective guidance for the new design.

In the design evaluation stage, the collaborative design organization participants and designers jointly discuss the design concept, verify the direction of the design team, jointly discuss the rationality of the design concept, provide suggestions for the modification and improvement of the design, and promote the design optimization to solve the design problems.

Combined with the computer-aided industrial design framework designed in cooperation, the project of automatic eco-monitoring vessel design was carried out. This project investigates the current situation of freshwater ecology at home and abroad, combines the research results of related fields of technology, and utilizes collaborative design and computer-aided industrial

design technology to design a water ecology management robot. The shape design adopts the bionic design research on fish, extracts the streamline curve of fish, and simplifies the figurative fish image at the same time, so as to design the shape.

4.1 Collaborative design expert team

Collaborative design uses participatory design methods to reduce cognitive biases between designers and users and to promote a better understanding of user needs. A typical participatory design team is oriented to a specific design context and consists of a small group of experts from various disciplines. The focus of collaborative design is on analyzing and understanding the project context and reaching a unified understanding of the solution that will result in a design solution. The collaborative design experts in this project consisted of industrial designers, environmental science experts, mechanical engineers, freshwater biologists, and others.

4.2 Automatic eco-monitoring vessel form reference database Design

During the pre-design phase of the project, the collaborative design team conducted data collection, literature research, and case studies related to the automatic eco-monitoring vessel. The collaborative team completed the development of the project-related form database through the overall of the relevant information.

4.3 Product Modeling Database

Design modeling is the evolutionary process of refining design sketch form solutions. The process of modeling the details of the form requires the use of some existing product modeling data as a reference. Building a modeling database through a collaborative design team can better assist the 3D modeler's work and can significantly improve modeling efficiency.

4.4 Product Rendering Related Databases

Product rendering related tasks include scene construction, lighting layout, material selection, etc. Through the professional background knowledge of the collaborative design team, building a database of product rendering parameters can effectively improve the rendering quality.

4.5 Collaborative processes in computer-aided industrial design

4.5.1 Intentionally related product form sketching.

The morphological design of the automatic eco-monitoring vessel was selected after brainstorming of the cooperative design team for sketching by hand, and finally six design sketches entered the evaluation session, in which the advantages of the interdisciplinary background of the cooperative team were given full play to the selection of the best solution.

4.5.2 Product modeling with design features .

The product modeling session was divided into three stages. In each stage, the collaborative team scrutinized the design proposal, and through three rounds of evaluation, the final modelling solution satisfies all the requirements of the interdisciplinary aspects of functionality and aesthetics, as shown in Figure 3.

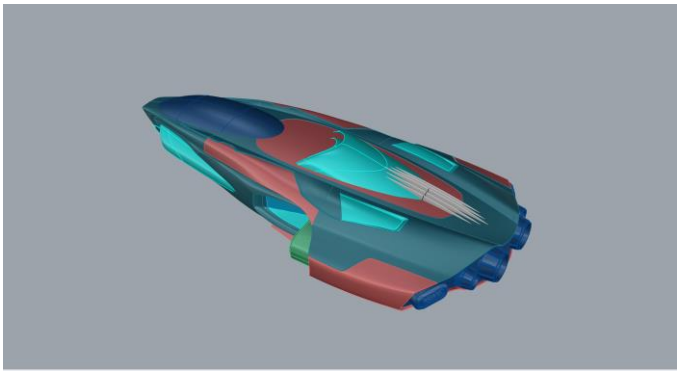

Figure 3 collaborative design in product modeling

4.5.3 Product rendering combined with design contexts.

The design team's professional examination of the product's exterior features in the model rendering. The team's assessment enables a better quality and rationalisation of the appearance of the proposal.

4.6 Collaborative CAID project evaluation

The project evaluation team consists of experts with knowledge backgrounds in interdisciplinary fields such as design, water ecologists, mechanical engineering, electrical engineering, and computer disciplines. The collaborative design team conducted two rounds of review of the six final designs. Data such as fixation time, blink count, fixation count and saccade time were collected through an eye tracker. Combined with the results of the eye-tracker data analysis, the optimal design solution for the eco-monitoring vessel was selected.

Table 1 Eye movement data of different design schemes

	Fixation time	**Blink count**	**Fixation count**	**Saccade time**
Scheme1	0.772	8.424	17.45	2.532
Scheme2	0.812	7.112	18.03	2.73
Scheme3	0.714	7.834	16.42	2.642
Scheme4	0.641	6.312	16.43	2.415
Scheme5	0.812	7.356	19.33	2.602
Scheme6	0.611	8.377	16.23	2.512

4.7 Final design of the eco-monitoring vessel

The interdisciplinary design team selected, evaluated and optimised solutions at several stages of the CAID process, using the collaborative design CAID process framework, resulting in a design that integrates design, mechanical engineering, computer technology and aesthetics to produce a final design with good engineering prospects. The final design for the automatic eco-monitoring vessel has good form, a logical functional layout and is a product design with multidisciplinary strengths, as shown in Figure 4.

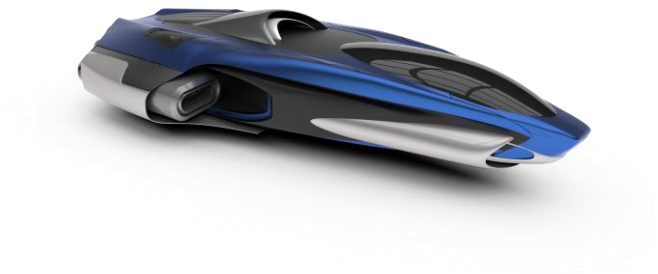

Figure 4 Final design solution

5 CONCLUSIONS

At the end of the final review of the design project, feedback on the design process was gathered through questionnaires and discussions among concept designers, model builders, product rendering designers, and jury members to assess the effectiveness of the collaborative design process over the traditional process. The following aspects were included: Firstly, consider whether the first step in this design process took into account those issues and parameters that had the greatest impact on the design. Secondly whether these issues were later translated into the goals and objectives of the project as a way to review the efficiency of the project. The third is whether the team of designers possesses an accurate understanding of the project's needs and goals. The fourth was whether the design project was outputting enough appropriate design concepts. The following are the results of the feedback.

Through the introduction of collaborative design, the project was able to take into account the issues and parameters that would have the greatest impact on the design, including the most important functions of the hull and the ways and means to achieve them. These functions were also effectively translated into the goals and objectives of the project, and the whole design project was closely focused on the theme of ecology and environmental protection. The designer team deepened the functions and purposes on this basis, and had an accurate understanding of the project needs and goals. The design project also outputs three theme-related design concepts. Through the above analysis, it is clear that the introduction of collaborative design has improved the efficiency and quality of computer-aided industrial design.

Through the implementation of this project, it was also found that the collaborative design approach provided better insight in identifying the issues to be addressed in the design. Collaborative design is able to bring the design target problem into a broader cultural context to think about. This provides a broader context for the final design to be used. The introduction of collaborative design was also found to increase the effectiveness of designers in making design decisions that take into account the needs, beliefs, values, and culture of the product's users, thereby better enhancing the likelihood of product success.

REFERENCES

[1] K.M. Kim, K. pyo Lee. (2016) Collaborative product design processes of industrial design and engineering design in consumer product companies. Design Studies, vol. 46: 226-260.

[2] H. Berends, I. Reymen, R.G. Stultiens, M. Peutz. (2011) External designers in product design processes of small manufacturing firms. Design Studies,vol. 32: 86-108.

[3] N.B. Dohn, S. Harnow Klausen, Situativity of different forms of knowledge, N.B. Dohn, S. Borsen Hansen, J. Jorgen Hansen (Eds.). (2020) Designing for situated knowledge transformation, Taylor & Francis Group, pp. 23-38.

[4] W.L. Bedwell, J.L. Wildman, D. DiazGranados, M. Salazar, W.S. Kramer, E. Salas. (2012) Collaboration at work: an integrative multilevel conceptualization. Human Resource Management Review, vol. 22 (2): 128-145.

[5] T. Robertson, J. Simonsen. (2012) Challenges and opportunities in contemporary participatory design. Design Issues, vol. 28 (3): 3-9.