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Eagle Model: A Future Medical Product Innovative Design Model Driven by Human-Technology Symbiosis and Co-Design

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ABSTRACT

Medical products are complex professional artefacts used in the medical situation, such as disease prevention, diagnosis, treatment, and rehabilitation, that hierarchically originate from basic medical research, medical process, and service process. With the coming of the ageing society and the experience economy era, both physical and experiential needs of people for medical products are becoming increasingly complicated, diverse, and comprehensive day by day. However, balancing the conflicts among various needs is still a significant challenge. This article explores a future medical product innovative design model driven following the ideology of human-technology symbiosis and co-design, named the Eagle Model (shaped like an eagle), as a potential proposal for this question. This model is constructed based on 50 design outputs in the last 3-year medical product design curriculum for bachelors in D&I, Tongji University, Shanghai, China. We hope this article can inspire other researchers in the medical innovative design area.

Keywords: Medical product innovative design, Medical co-design, Human-technology symbiosis, Multidisciplinary collaboration

INTRODUCTION

Medical products are complex professional artefacts used in the medical situation, such as disease prevention, diagnosis, treatment, and rehabilitation, that hierarchically originate from basic medical research, medical process, and service process (IEC and ISO, 2015, 2016; Palmer *et al.*, 2019; Branaghan *et al.*, 2021; Durfee and Iaizzo, 2021; Nadeem and Weiss, 2021). Classified by use, medical products can be divided into scientific research, teaching, and clinical medical products. With the coming of the ageing society (Santoro, Vera-Munoz and Belli, 2017) and the experience economy era (Pine and Gilmore, 1999), both physical and experiential needs of people for medical products are becoming increasingly complicated, diverse, and comprehensive day by day (Jones, 2013). According to statistics, in 2020, the market size of the global medical product industry was 484.05 billion dollars, with a year-on-year growth of 4.6%. It is expected that the scale of the global medical product industry will reach nearly 579.30 billion dollars by

2025. Especially in China, by 2020, the scale of the medical product market was about 112.28 billion dollars, with a year-on-year growth of 15.5%, which was close to 4 times the global growth rate of medical products. China has also become the world's second-largest medical product market after the United States. (Xue *et al.*, 2008; China National Center for Biotechnology Development, 2010; Cushman & Wakefield, 2021; Wang *et al.*, 2021; Brand Finance, 2022; Han, 2022; iResearch, 2022; Zeng, 2022).

Because of the extremely high professional threshold, complicated stakeholders, and strict regulation of security and usability (Martin *et al.*, 2008), the design and development of medical products require the deeply integrated participation of multiple disciplines, especially *Medicine*, *Design*, and *Engineering*. However, integrating the strengths and balancing the conflicts among various disciplines are still significant challenges. For instance, how to harmonize the innovativeness of Design and the normalization of Medicine?

This article explores a future medical product innovative design model driven by the ideology of human-technology symbiosis and co-design, named the *Eagle Model* (shaped like an eagle), as a potential proposal for this question. This exploration is based on the teaching experience.

MEDICAL CO-DESIGN NEEDS BOTH HUMAN AND TECHNOLOGY

With the development of technology and social progress, the object of design is also evolving - from a product that initially only responds to a single functional need to a complex system that meets multiple values of stakeholders, integrates multiple disciplines, and embeds a large number of advanced technologies (Buchanan, 1992; Lou, 2018). This evolution also brings new challenges to designers, divided into two main aspects: (1) if the design object will cause multiple value conflicts among stakeholders, how can designers coordinate and resolve these conflicts in the design process? (2) If the needs of the users served by the design object are far beyond the boundaries of the designer's understanding, how can the designer respond well to these needs in the design process?

Co-design provides a way for designers to address these challenges. In Sanders and Stappers' definition, co-design is a design development process in which designers work with people not trained in design to be creative (Sanders and Stappers, 2008) to make the design more fit for purpose. Kleinsmann and Valkenburg, on the other hand, identify in more detail the work done by the individual participants in co-design, i.e., sharing their knowledge about the design process and design content, building a common understanding, and realizing the design of a new product (Kleinsmann and Valkenburg, 2008).

Combining the findings of related scholars and from its perspective as a group activity involving multiple parties, the author defines co-design in this study as a method of using group intelligence to solve complex design problems that individual designers' intelligence cannot solve. Co-design is commonly used in particular fields with high barriers of expertise, such as medical (Bate and Robert, 2006), aviation (O'Sullivan, 2006), chip (Shakeri and Meindl, 2005), and chemical (Li and Wang, 2019), or social fields with

Table 1. List of common areas and usage aim of co-design.

Common Areas (Ranked by Literature Quantity)	Usage Aim	
	Value Conflict	Knowledge Barrier
Computer Science (866)	×	√
Health Care (613)	√	√
Social Innovation (489)	√	×
Engineering (96)	×	√

Table 2. List of the recent 3-years curriculum materials.

No.	Time	Grade	Subtopic	Team Number
1	2020.05	3	Health Life	13
2	2021.05	2	Breath & Health	13
3	2022.04	3	AI + Healthcare	10
4	2022.06	2	Future Health Driven by Technology	14

significant multiple value conflicts, such as community (Deakin, Lombardi and Cooper, 2011), children (Thabrew *et al.*, 2018), and elderly (Xie *et al.*, 2012).

The common areas of co-design (top 4 by literature quantity) and their target uses are listed in Table 1, based on 2210 journal articles obtained by the author on October 14, 2022, in Web of Science and Scopus, using "co-design* or co-design*" as the search formula.

As can be seen, the usage aim of co-design in healthcare has a particular specificity, i.e., it is used not only for the reconciliation of multiple value conflicts (human end) but also for the crossing of knowledge barriers (technology end). In other words, we need to consider both *human* and *technology* when co-designing a medical product. This requirement leads us to construct a medical product innovative design model driven by human-technology symbiosis and co-design in this article.

MEDICAL PRODUCT DESIGN CURRICULUM IN D&I

Several years ago, we initiated a curriculum of medical product design for 2nd-3rd year undergraduates majoring in industrial design at the College of Design and Innovation (D&I), Tongji University, Shanghai, China. This curriculum series has already become a critical stage for students and a representative teaching achievement for D&I.

Considering the data's variability, timeliness and completeness, we selected the recent 3-years curriculum materials for further analysis in this article. The detailed information on these materials is in table 2, and the product design renderings are collected in figure 1.

During the teaching process year by year, we gradually realize some common problems that most preliminary medical designers will probably encounter:

Figure 1: Output collection of the recent 3-years curriculum.

(1) *Unconscious easy-way preference*. Because designers are often emotional people who lack systematic medical knowledge, they unconsciously take easier ways during the medical design process. The Easier way means more emotional, including experience, service, communication, and lifestyle. According to the statistics, over 80% of teams in these four curriculums have performed this unconscious easy-way preference.

(2) *Lost in the unnecessary mass learning*. Because designers often have no idea about a specific medical topic, they are eager to find as many learning sources as possible at the beginning of a medical design project. However, as a designer, no matter how much medical knowledge he or she learns, there are still bound to be many misunderstandings. As one of the leading figures in medical design, professor Xiangyang Xin has also said, "Although I have paid attention to and participated in the design of the medical and healthcare field for about six years, I am still far from mastering enough expertise in the medical and health care field" (Xin and Wang, 2014). We have seen too many students lost in the unnecessary mass learning in the curriculum during these years.

(3) *Too innovative or too practical*. Medical products are complex artefacts with the perfect balance of innovativeness and normalization. However, design outputs in the curriculum demonstrate that this balance is hard to achieve. Some outputs may be too innovative to have any practical meaning for today's life, while others may be too practical that they are just a small optimization from the experience or appearance aspect of current products.

CONSTRUCTION OF THE EAGLE MODEL

Driven by the three common problems mentioned above, this article explores a potentially more comprehensive model to describe the structure and factors of medical design, and instruct the preliminary medical designers better to start their work.

Based on the teaching experience, unstructured observation, and outputs analysis of this curriculum, we propose the hypothesis of the Eagle Model. As shown in Figure 2, this model is constructed following the ideology of human-technology symbiosis and co-design. It is composed of the principal

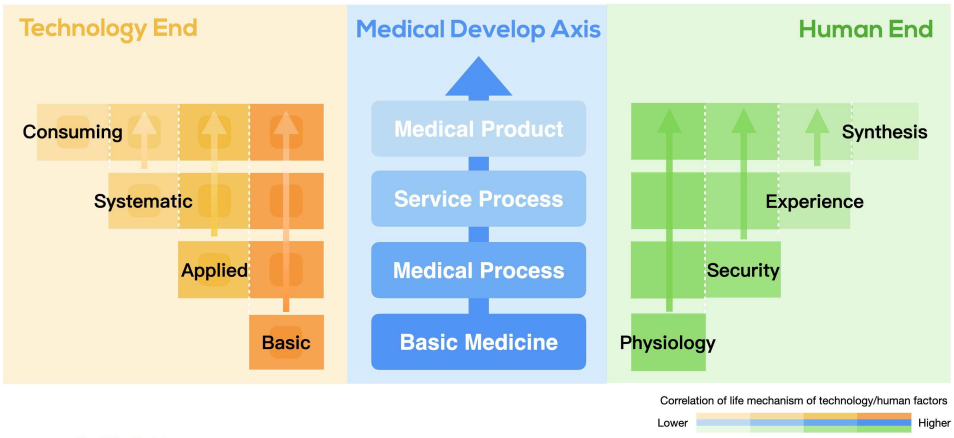

Figure 2: Schematic graph of the eagle model.

medical axis in the centre line as the "body", with the technology axis on the left and the human axis on the right as the "wings". Each line is constructed by four layers from the basic factors (basic technology - basic medicine - human physiology) to applied factors (applied technology - medical process - human security), to service factors (systematic technology - service process - human experience), and finally to product factors (consuming technology - medical product - human synthesis).

The following is a detailed explanation:

(1) *The principal medical axis in the centre line*. By delineating the scope of medical innovation research that is distinct from the traditional scope of medical design work, it was determined that basic medicine, medical process, service process, and medical product would be included in the scope of medical innovation (Boyd *et al.*, 2012; Jones, 2013; Donetto *et al.*, 2015; Robert *et al.*, 2015; Liu *et al.*, 2020). Based on the protection of human life safety and physiological health, we expand to user-level research on medical services and products.

(2) *The technology axis on the left*. Integrating the new economic growthism theory SLIM minimal linear model in economics (David, 1992) and the theory of technological excess in sociology (Geels, 2002), while referring to the classification of technology by the Chinese Association of Science and Technology (CAST, 2022), we correspond technology to medicine & human and consider its relevance to life mechanisms. We expand the multi-application scenarios of technology transformation from the scientific and consumer levels to maximize the innovation opportunities of technology based on compliance with safety standards, laws, and regulations.

(3) *The human axis on the right*. From the historical dimension of human factor engineering development (Dreyfuss and Tilley, 1993; Dreyfuss, 2003), human factor consideration is embedded in every level of medical product innovation, focusing on forward-looking technology, innovative product form and concept based on the full-dimensional

exploration of future human-computer interaction, considering the moral ethics and sustainable direction of human well-being on top of emotional experience, scientifically answering the value of product innovation and ease of use, and defining interaction experience standards and norms. Facing the present and future in the field of medical innovation, covering product innovation, promoting the overall profound innovation and upgrade of medical health from a multidimensional and comprehensive perspective, providing a comprehensive human factors engineering reference for creating Chinese medical innovation products, and taking performance and well-being as one of the critical factors to be considered in concert with medical services and technical safety.

CONCLUSION

This article initially constructs an innovative design model of medical products driven by the ideology of human-technology symbiosis and co-design based on the teaching experience of many years. We plan to continue iterating it by evaluating it with experts, putting it into the next-year medical product design curriculum at Tongji and executing a series of innovative design practices. We hope this article can be an initial inspiration for the relative researcher.

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