Designing "Height" into Daily Used Products - A Case Study of Universal Design

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Abstract. Universal design is an approach to design daily used products that are usable by all people to the greatest possible extent. However, successful application of universal design requires an understanding of human performance. Ergonomic considerations are a part of "universal design" and should be taken into account by manufacturing engineers in product development. Integration of ergonomic considerations into the manufacturing processes becomes a major marketing strategy. Therefore, the purpose of this paper is intended to explore the relationship between body dimensions and the "height" of consumer products. A "user/product/effect" model is proposed to study how to design "height" into products and the results are discussed.

Keywords: Universal design, human factors, anthropometric data, consumer product.

1 Introduction

'Height' plays an important role in product design. Product dimensions which are too high or too low can make users uncomfortable. Thus 'height' is one of the key factors in product design that can offer most people a comfortable use and feel. The 'height' of consumer product influences product use in our daily life, such as the height of a table, chair, handle, or public telephone. For example, school furniture from manufacturers is typically not designed to accommodate different individual user dimensions. While a few desks offer an overall height adjustment and chairs of different sizes, individual adjustments for the seat, arm and back are not offered [8], [16].

Taking school furniture as an example, children are repetitively exposed to the hazards of abnormal or awkward postures due to classroom furniture that is often either too big or too small. Because children vary widely in their anthropometric measurements, both across age groups and within the same age group, all chairs and desks do not fit all children. To achieve a proper fit between school furniture and students, and to promote proper posture, the design of school furniture must recognize and reflect variations in anthropometric measurements across children of different sizes and cultures [9], [17].

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Previous studies have been shown that anthropometric measures and the performance of activities, in addition to specific design features of school furniture are all factors that influence the postural health of school children. It is assumed that chairs and desks in classrooms fit all children; however, adjustability and variability of furniture provided in the classroom is needed to satisfy a student's postural and educational needs [1], [2], [6], [10]. Ergonomic considerations are very important for school furniture design, since students most of their time performing a large number of activities. The most important consideration for designing daily-life products is "designing for human use," while the concept of universal design is "designing for all users." “Universal Design” is one of the most important issues in the design field. In the past, “Universal Design” was a concept of user-friendly design for creating barrier-free environment. Today, many people mistake ‘Universal Design’ as limited to designing for elders and the disabled. In fact, the main and original concept of universal design is ‘Design for all of people’ and ‘Allow use by more people’.][22].

The anthropometric database is used as a design reference for daily used product design. However, the most effective application of such data in product design is another important issue. Ergonomic considerations and manufacturing principles can sometimes present conflicting recommendations for design. The optimal product design must consider both of these objectives for developing guidelines that integrate ergonomics and manufacturing principles. In this way, product design can both improve response to consumers’ needs and maximize profitability for manufacturers [18]. Therefore, this study focuses on the application of anthropometric data by presenting three case studies of ‘universal design’ for developing design guidelines that integrate ‘ergonomic considerations’ and ‘manufacturing principles’ in designing ‘height’ into daily used products.

2 Ergonomic Considerations Regarding “Height”

2.1 Anthropometric Data

The most important ergonomic consideration for designing daily-life products is ‘designing for human use.’ However, cost conflicts between optimizing the design for ergonomics and manufacturing often appear, especially when the issue of applying anthropometric data is addressed. In ergonomic considerations, the requirement in anthropometric design is to determine a value for some design parameter in terms of a percentile cutoff for an anthropometric value in order to meet a target percentage for a population of interest. For example, what is the require range of seat height adjustability to accommodate 90% of the user population? In many anthropometric problems of "fitting" some design, it is necessary to consider several anthropometric variables simultaneously. For example, what will be the actual percentage of users who can be accommodated by equal 90 percentile cutoffs on ‘knee height’ (knee space) and ‘sitting height’ (head space), and what are the equal percentile cutoffs to be set if the target bivariate percentage is 90% Such design problems become more complicated because the designer needs to consider the correlations between body dimensions. [20].

2.2 Universal Design

Ergonomics has traditionally been used to decrease the number of occupational injuries by discovering those postures and tasks that create significant musculoskeletal stress. However, the principles which underlie ergonomics can potentially be used to improve productivity as well. Therefore, integration of ergonomic considerations into the manufacturing processes is a major marketing strategy [3]. For example, school furniture from manufacturers is typically not designed to accommodate different individual user dimensions. While a few desks offer an overall height adjustment and chairs of different sizes, individual adjustments for the seat, arm and back are not offered. Instead, a one-size-fits-all philosophy (universal design) has been adopted in the industry, because such furniture is less costly to manufacture and easier to sell at a lower price, and lessens the inventory problems for manufacturers and schools. Universal design can be defined as the design of products and environments to be usable to the greatest extent possible by people of all ages and abilities (the Center for Universal Design, 1997). Today, ergonomic considerations are a part of "universal design" and taken into account by manufacturing engineers in product development.

2.3 Comfort Factors

The factors involved in determining the comfort of school furniture are complicated, including ergonomic (user/product/task) and manufacturing considerations [15]. The study of the identifying factors of comfort shows that the three dimensions influencing school furniture design are "comfort factor," "design factor," and "spatial factor."[4], [5], [6], [7], [11], [24]. The comfort factor relates to the application of anthropometric values such as seat surface height, desk surface height, etc. The design factor focuses on form, material, and color features. The spatial factor relates to layout issues such as storage space. These three factors are used as references in the design of both separated and combined-type desk and chair. The designer should keep the user-product-task model in mind throughout the design process. The design development is optimized by considering the comfort factors and the relevant anthropometric variables influencing the design. The design first considers the ergonomic dimensions of the desk and chair, taking into account user/product/task analysis, and then adds manufacturing considerations.

3 Three Cases Study of “Height”

3.1 A Case Study of School Furniture

Lin and Kang [14], [15], [16], [17] conducted a series of studies of ‘height’ by combining ‘ergonomic considerations’ with health in designing high school furniture in Taiwan. Chairs and desks do not fit all children equally as well because they vary widely in their anthropometric measurements. The studies presented a paradigm for taking ergonomic considerations into human performance in health for universal design in order to achieve a proper fit between school furniture and students.

Ergonomic Dimensions. Using anthropometric data in design involves art as well as science. However, in the use of such data for designing daily-life products, there are generally two aspects: 1) determine what anthropometric design principle should be applied, and 2) how to achieve the anthropometric considerations in the most cost effective manner. When applying anthropometric data, three anthropometric design principles must be considered: extreme individuals, an adjustable range, and the average. Based on these principles, the recommendations of ergonomic dimensions for the ideal school desk and chair were proposed. For examples, some dimensions are adapted for the average, e.g. seat depth; some dimensions are adapted for the extreme individual, e.g. seat width; and some dimensions are adapted for an adjustable range, e.g. seat and desk surface height [4], [13], [19].

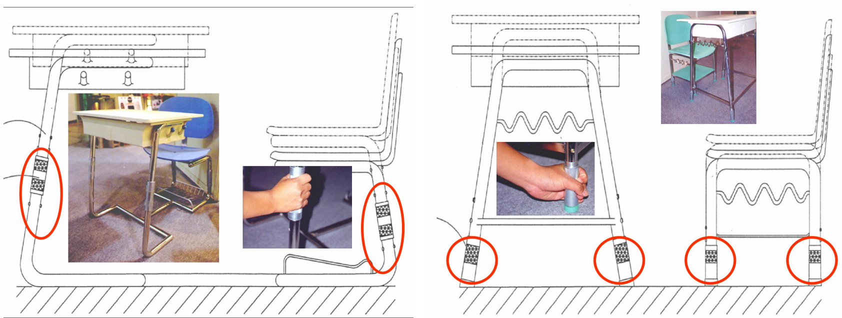

Fig. 1. Adjustable devices in combined-type and separated-type desk and chair

Adjustable Devices. Previous studies support the need for adjustability or incrementally sized school furniture in classrooms to accommodate the variation in anthropometric measures across different age groups. Generally, designing for an adjustable range is the preferred method of design, but it is not always possible. In this study, the sitting height and desk height can be adjusted to the individual occupant. Two adjustable devices are designed using a spring and screw structure to provide for adjustments to cover a wide range of users. For the separated-type design, the adjustable dimensions are seat and desk surface heights (Figure 1, right). For the combined-type design, the dynamic dimensions that can be adjusted include desk height and sitting height, and the distance from seat to desk (Figure 1, left). The range from the 5th percentile female to the 95th percentile male is divided into three different ranges. For manufacturing convenience, the same screw structure is used in the adjustable devices.

Furthermore, another design approach proposed a new way to adjust the height of desks and chairs. The previous adjustable devices for the desk and chair drawer have been changed as shown in Figure 2. The desk and chair system will vary only in the waveform of the drawer. Students can adjust the height of desk and chair by using the waveform design. With this design, using only a set of steel pipes will make it possible to meet the requirements of ergonomics and manufacturing considerations.

Fig. 2. Adjustable desk drawer for adjusting desk height

3.2 A Universal Design Case Study from Japan

Aoki Makoto [24] established a free website related to the concept of appliances for the aged, general public, and barrier free design supported by an organization of barrier free supporters in Japan. This website provides and discusses several general concepts of universal design - in particular, 'height' issues in products used daily. Appliances for the aged mean that the product is just designed for the aged. The appliances for the general public mean that the product is designed for just the general public. Barrier free appliances are products not only for general public, but also for the aged. So, barrier free appliances are a complete concept of "Universal Design" which does not target a particular group or range limit, but instead is "Design for all of people."

3.3 A Case Regarding Universal Design of 'Height'

The 'highchair' at the center of figure 3 was designed by Maartje Steenkamp who is one of designers of Droog Design and won the 2006 Red dot award. The product is a typical universal design product in that the 'height' of chair could be adjusted along with the child's growth. While the child is growing up, the chair can be adjusted lower and lower. The design allowed a child to continue using the highchair even as he continues to grow. The parent need not worry about how long the chair could be used for the child because it provides the adjustable height to fit the child's growth. The adjustable highchair could thus be adjusted to the user's need which is the main and original concept of Universal Design - 'Allow use by more people' [25].

4 The User/Product/Effect Model

Much of the research organization and design philosophy follows a user/tool/task system design model presented by Kreifeldt [18]. The model showed the interactions in a user/tool system and in particular emphasize the three-fold objects of the design: user, tool (product), task; the two interfaces: the user-tool interface (manipulation), and the tool/task interface (engagement), and a number of interactions in the system. Based on the user/tool/task model, the concept was applied to universal design by exploring the relationships between appliances for the aged, the general public, and barrier free [24]. A user, product and effect paradigm is proposed in Figure 3a where the intersection area between the user and product is the 'effect' showing the extent possible to the user's need. A larger 'effect' area signifies that the user is fit better meaning greater comfort for users in using the product. Taking the 'highchair' as an example, the moving circle represents that as the child is growing the intersection becomes smaller and smaller (Figure 3b); if the product does not provide any ergonomic considerations to fit the user need at the same time, the effect will be from small to non-intersected as shown in Figure 3c.

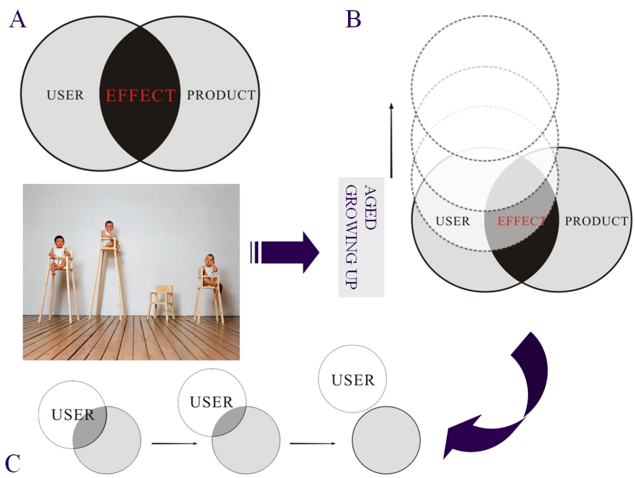

Fig. 3. The relationship of user/effect/product

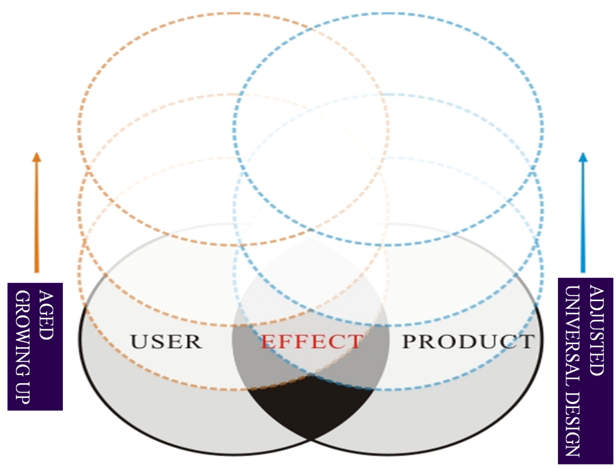

Fig. 4. The user/effect/product model

When the highchair is adjusted by changing its 'height', the child can fit that chair dimension and use it comfortably. This is a process of aging or growing up for the user side and adjusting and universal design for the product design side. The model was used to develop the design 'height' into the product as shown in Figure 4. It is known that the real situation is more complex than this. Under normal circumstances, the designer involves ergonomic considerations to design the product, which employs 'effect' to complete the product design. Therefore, the effect is the key factor for ergonomic considerations and universal design.

5 The Application of User/Product/Effect Model

The user/product/effect model is proposed to solve the variety of human dimensions, focusing on the problem of a growing user, and then on the effect of the product. In general, designers often only focus on 'usability' and 'manufacture'. Thinking within this small range limits design development. But when designers think about "human", "society", and "environment", designs could not only benefit the product, but also improve human welfare and social environment [22]. Based on the user/product/effect model, two design cases are proposed to show the subject of 'height' in our daily used product design.

5.1 Case one – School Furniture

In today's classroom, children vary widely in their anthropometric measurements, chairs and desks do not fit all children. Especially, the 'height' of school furniture is very important for school furniture design, since students perform a large number of activities and spend most of their time with them. Can the same school furniture fit all individuals who have different body dimensions? The answer is obviously negative. Based on the research of Lin and Kang [14], a new design takes 'height' into design by considering the relationships between user, product and effect as shown in Figure 5. In this design, the sitting height and desk height can be adjusted to each individual by using an easy joint to accommodate the variety of anthropometric data across different age groups.

Fig. 5. The relationship of user/effect/product for school furniture

5.2 Case 2 – Public Furniture

In today's fast-food restaurants such as Mcdonalds, and Kentucky Fried Chicken, the same public furniture is provided to the variety of customers. After ordering, consumers take their meal on a tray to find their seats. Does the variety of customers use the same size furniture when they're eating? Of course not, so the other design for public furniture uses the concept of universal design which provides three kinds of height adjustments as shown in Figure 6. The public chair is made of metal tubes which will let a consumer put the tray into the one which provides the most comfortable height to eat.

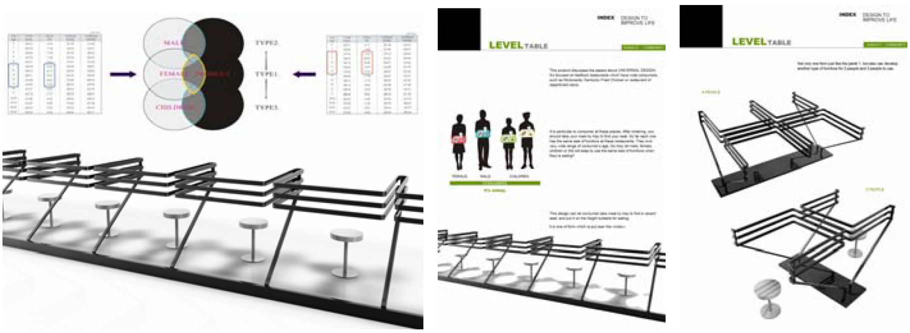

Fig. 6. Designing 'height' into public furniture

6 Conclusion

Universal design is an approach to creating everyday environments and products that are usable by all people to the greatest possible extent. By using universal design, companies can maximize their potential market. However, successful application of universal design requires an understanding of human diversity (ergonomic considerations). Design and manufacturing engineers seem well aware that the most efficient way of improving ergonomics in manufacturing areas is during the early phases of product development. This paper presents a paradigm of how to take ergonomic considerations into manufacturing for universal design. Based on the 'Universal Design', the paper focused on product height and discussed its influence on users. Furthermore, this paper uses the user/product/effect model for the concept of "Design for all of people". It will provide a model for designers and students for designing height as well as for other aspects into products in the future. Two cases show the design of products based on adjustment for user variation. Naturally, all such designs must use the relevant anthropometric data as well as testing and verification.

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