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Kano Model and QFD integration approach for Ergonomic Design Improvement

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Abstract

Increasing consideration has been given to Ergonomics in product design since the last several decades. Nowadays, more companies apply ergonomic aspects to their products to fulfill customer requirement and satisfaction of new products development. Customer requirement and satisfaction measurement can be achieved through various methods. This paper presents joining methods of Kano Model and Quality Function Deployment to improve the school workshop's workstation design for adolescent in terms of ergonomic and users need. A survey was done to 336 students to identify problems of the current workstation. Data gathered was translated into Kano questionnaire and answered by 255 students. Then it was clarified and used in the House of Quality matrix. At the end of the study, we find that both methods were able to prioritize the modification elements to be implemented into the new ergonomically designed workstation.

Keywords: Kano Model; House of Quality; school workshop; workstation; student; ergonomic design improvement

1. Introduction

School workshop is provided as school facility in order to be used as technical and vocational education class. In Malaysia, this kind of subject is called Integrated Living Skill, which in objective of preparing students to real job based on manual and practical activities (Ministry of Education, 2002). The

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major function of school workshop is to support practical activities and as an alternative classroom purposely for Vocational education. Just like other facilities in school such as classroom and laboratory, workshop's workstation has great impact in teaching and learning activity. Students need good furniture to sit/stand comfortably during teaching – learning process. Sam Murphy et al. (2004) stated that children are more likely to adopt flexed postures while working at the desk, with truck flexion more than 20° prone to suffer from postural discomfort in school. Therefore, not ergonomically designed school furniture may generate growing back pain to children in the future. As suggested by Jfm et al. (2003) , the size of school workstation should be based on their stature, rather than any other body segments. These sizes should be matched to anthropometry characteristics of at least 50th percentile of the user population (Milanese and Grimmer, 2004). They also made an assumption that there is an optimal relationship between anthropometry characteristics and furniture dimensions which would result an increased symptom of spinal and back pain.

This research was conducted at a rural secondary school in Klang district of Selangor, Malaysia. Workstation in the school workshop consists of a worktable to be shared by four to five students at a time. As a practical subject, students need to make a product made of woods and composite materials. This woodworking project must be completed usually within three to four months for every student. From author's observation and investigation, most students complained of back and muscle pain while using the workstation. A pilot study was carried out and results showed eight teachers and ten students, who completed a survey questionnaire, confirmed that 44% of subjects rated the workstation as average in comfort and 39% rated discomfort. 67% and 72% of subjects experienced back and neck pain respectively. This result proved that there are risk factors in the school workshop that can contribute to musculoskeletal disorder.

The objective of this study is to demonstrate how Kano Model and quality function deployment (QFD) were able to improve the design of school workshop's workstation via ergonomic design.

1.1. Ergonomic design

Most companies always concentrate on developing and enhancing product design in order to fulfil customer satisfaction. Sometimes, the design cannot satisfy all user expectation and ergonomics in the design process. Overall stages of product development usually are handled by engineering specialist. The absence of ergonomist for example may result in undesirable product design (Marsot, 2005). Ergonomic design considers upon users capability and limitation while handling the products, workstations and machineries (Helander and Lin, 2002). Ergonomic design knowledge is focused on the relationship of objects and environments with human factors. This knowledge is very important for design engineers when making crucial decisions regarding the ergonomic parameters for product and layout design (Kaljun and Dolsak, 2012). In human – workstation interaction, it is important that the workstation should be adapted to the task so the task should fit to the man. As such, ergonomic design of workstation and furniture must be based on the anthropometry and biomechanics of a human body (Oyewole et al., 2010).

Several studies have implemented the ergonomic oriented-designs were done by Park, Liu and Paschoarelli. Park demonstrated a new design workstation chair to minimize physical discomfort and the risk of Cumulative Trauma Disorder (CTD) in Video Display Terminal (VDT) workstation. The ergonomically-designed chair attached with keyboard-mouse support was proven more suitable for computer work because it was able to decrease muscle activity (Park et al., 2000). A helmet design suggested by Liu based on head shape had successfully improved the helmet's stability and reduces its weight. Ergonomic aspects were easier to be considered with the integration of helmet and human head

modelling. Using 3D human head anthropometry measurement as reference, preliminary design has shown improvement in efficiency and fitting comfort (Liu et al., 2008). A systematic assessment procedure was presented by Paschoarelli to evaluate the redesign of ultrasound transducers. This study defined that an organized methodology procedures of recording and analyzing movement and perception in product development phase were able to generate important information for more effective products' improvement (Paschoarelli et al., 2008).

2. Kano Model and QFD application review

Noriaki Kano was the first person to develop a method to identify user requirement and expectation through a preference classification technique (Kano et al., 1984). Kano Model is able to determine user requirement and exceed their expectation. There are three categories of requirements which influence user satisfaction in different ways (Sauerwein et al., 1996):

- Must be – user expect the qualities and will be dissatisfied if they are not fulfilled.
- One dimensional – user will be satisfied if the qualities are fulfilled and dissatisfied if they are not fulfilled.
- Attractive – exceed user expectation, but if they are not met, user will not be dissatisfied.

Quality function deployment (QFD) is a powerful tool in product development to translate the voice of customer in engineering design quality that fulfils customer satisfaction. It is also an ultimate tool to increased time and resources saving throughout all stages – design to production planning (Nikhil Chandra Shil et al., 2010). Sireli et al. (2007) also stated QFD can help to evaluate the impact values of design requirement characteristics on meeting customer requirement expectations by prioritizing the design requirement based on their important values.

However, some constraints such as limit of space to occupy the workstation and cost may change the design outcome which some of requirement features cannot be met. Practically, one should try to maximize user satisfaction and apply ergonomic and safety features to make sure the workstation design would be positively acceptable. According to Lai et al. (2004) , higher quality is defined by meeting the customer requirement. But due to some constraints, such as financial and manpower limit, QFD as optimization method is needed to exploit the use of resources available.

2.1. Kano questionnaire development

The Kano questionnaire development was constructed by direct user contact through interview. They gave their opinions regarding the current workstation. All relevant comments and suggestions regarding ergonomic consideration were included in the questionnaire. 336 students volunteered to participate in the interview session.

260 set of questionnaires based on Kano Model were distributed among 14 and 15 years old students and 255 completely answered forms were returned. The effective questionnaires response rate was 98%. Cronbach alpha values for the questionnaire were 0.705 and 0.726 which means the questionnaire is reliable to be used in this study. According to Piaw, the acceptable value of Cronbach alpha is between 0.65 to 0.95 (Piaw, 2006).

Table 1. Samples Demographic Data

Age	Gender	Frequency
14 year old	Male	102
	Female	76
15 year old	Male	28
	Female	49
Total		255

There were four factors of 11 qualities in ergonomic scope to be evaluated using Kano Model method. Table 2 showed each quality classification and description.

Table 2. Qualities classification

Factor	Quality	Description
Size	Broad work surface.	Size of the working table to be shared by four to five people at a time.
	Workbench height.	Suitable for variety of body sizes.
	Stool/chair height.	Suitable to work with a fixed working table height.
Design	Adjustable furniture.	Some suggest to be implemented to the workstation.
	Temporary storage.	Temporary place/container to put materials and tools.
	Additional tools.	Advanced tools for better working performance.
Comfort	Leg room.	Enough space for leg position and proper feet rest.
	Back rest.	A proper back support for sitting work.
Safety	Stable workstation.	The workstation must be sturdy and robust in design.
	Smooth working surface.	Avoiding damage to materials.
	Safety design and application.	Secure electrical wiring, no sharp edges, and additional safety devices such as clamps and vices.

2.2. Kano questionnaire result

Data analysis was treated by SPSS 17.0 software. All qualities were measured and classified in four categories; **Must – be (M), Attractive (A), One – dimensional (O)** and **Indifferent (I).** Indifferent category is defined as users do not care whether the quality is present or not. This type of quality does not effect user satisfaction at all. Figure 1 showed the two – dimensional Kano's model of customer satisfaction. Each quality was needed to determine the customer satisfaction coefficient. (Berger et al., 1993) suggested a solution in identifying relative values of meeting user satisfaction or not. But at the same time, preserving these four categories and separated values into two condition; better and worse.

$$Customer\ satisfaction,\ CS\ (better) = A + O / (A + O + M + I) \tag{1}$$

$$Customer\ dissatisfaction,\ CD\ (worse) = O + M / (A + O + M + I) \tag{2}$$

Based on above equations, it was easier to identify whether qualities offered will fulfil user satisfaction or prevent the user from dissatisfaction. According to Wang and Ji (2010), calculating CS and CD values can reflect the average impacts of each quality provided to customer feeling of satisfaction.

From table 3, it was clear that user expected safety quality and decided it as must-be category. This quality must be included in the design as they thought safety is the basic requirement for a workstation. However, broad working space was classified as one-dimensional category and user would be disappointed if it is not present based on CD value. Back rest for the chair also has almost the same value as broad work surface even though it was defined in Indifferent category. Results emphasized that students expects of safety qualities and will be satisfied if they were fulfilled with safety design and stable workstation. While qualities which will dissatisfy the user if not present are broad working space and chair back rest which are more in comfort category.

Table 3. Qualities classification

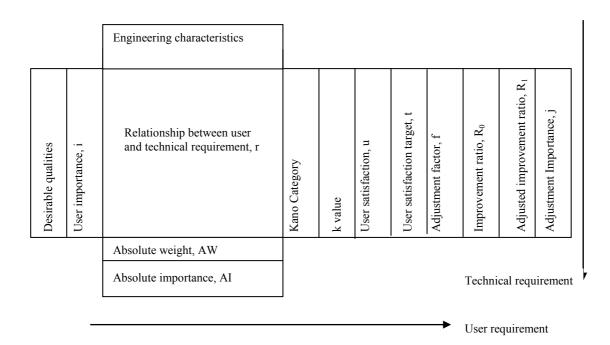| Factor	Quality	Category	CS	CD
Size	Broad working space.	O	0.58	0.48
	Workbench height.	I	0.43	0.33
	Stool/chair height.	I	0.43	0.23
Design	Adjustable furniture.	I	0.16	0.38
	Temporary storage.	I	0.19	0.24
	Additional tools.	I	0.47	0.45
Comfort	Leg room.	M	0.52	0.32
	Back rest.	I	0.47	0.47
Safety	Stable workstation.	M	0.62	0.33
	Smooth working surface.	M	0.60	0.39
	Safety design and application.	M	0.73	0.27

2.3. House of quality development

Fig 2. Illustration of the House of Quality (HoQ)

QFD approach is widely used to determine design characteristics of a new or improved product. Most important phase in QFD is the development of the House of Quality (HoQ). Figure 2 showed a diagram of main parts of the HoQ to be implemented in this study. Results obtained from Kano Model method were integrated into the HoQ. HoQ completing stage is a critical phase to determine certain characteristics as priority to be implemented into a product. From the result previously presented in this study, user expectations were achieved through interview and Kano Model analysis. Two steps in the workstation evaluation were proposed under this procedure. Both steps can provide accurate outcomes of evaluating user expectation in a school workshop's workstation.

For user requirement steps, it started with the list of desirable qualities. These were already achieved through Kano Model approach done previously. All relevant qualities were included in this part. This part is called the 'What' list. Second column is user importance, i which was obtained from a survey conducted to 205 students who used the current workstation for at least one hour and 45 minutes a week. Each student was asked to rate the importance of each quality in Likert scale (1=Unimportant to 5=Most important). User importance was the rate classification in range of 1 as less important to 5 as most important. The third column is the relationship determination between Desirable qualities and Engineering characteristics. The main reason of the interrelationship is to establish a connection between 'What' and 'How'. In order to fulfil user requirement, some technical elements need to be addressed depending on how they were relevant to one another. The forth and fifth columns are the Kano category and its k values. The k value is decided according to extended options by Chaudha et al. (2011) in which value of k is defined as 0, 0.5, 1 and 1.5 for Indifferent (I), Must-be (M), One-dimensional (O) and Attractive (A) respectively. The sixth column is user satisfaction, u. The value was the mean calculated for each quality from the user importance survey. The seventh column is the target expectation for each quality, defined by the users themselves from the user importance survey. The eighth column is the adjustment factor, proposed by Tontini (2007) to be used directly in the QFD matrix.

$$Adjustment\ factor = max\ ([CS], [CD]) \qquad\qquad (3)$$

where; CS = Customer satisfaction
        CD = Customer dissatisfaction

The ninth column is for Improvement ratio in order to measure user satisfaction degree for each user attribute to each qualities listed. Tan and Shen (2000) suggested a calculation to describe the user satisfaction improvement ratio as

$$Improvement\ ratio,\ R_0 = t\ /\ u \qquad\qquad (4)$$

where; t = User satisfaction target
        u = User importance

An adjusted improvement ratio, R_1 was recommended by Chaudha et al. (2011) which utilized important parameters from Kano method to be contributed in QFD matrix. This result can give the absolute importance to derive the final analysis.

$$R_1 = (1 + f)^k\ x\ R_0 \qquad\qquad (5)$$

where; f = Adjustment factor
        k = Kano Category
        R_0 = Improvement ratio

The last column is Adjustment Importance, j which was obtained from multiplying the adjusted improvement ratio to user importance (Garibay et al., 2010). This value can give clear understanding of prioritizing the qualities expected by target users.

For technical requirement step, it begins with the engineering characteristics row. These characteristics were important to meet the desirable qualities. In addition, some limitation should be identified in order to adapt with current situation and environment. But at the same time, user satisfaction must be delivered. This part was called the 'How' list. Then, it is the relationship determined between Desirable qualities and Engineering characteristics. After that, it is the Absolute weight, AW which is gathered from the sum of multiplication of user importance with the relationship of each characteristic. Absolute weight gave the information to prioritize specific characteristics that were important in designing the new workstation based on user importance. Finally, the Absolute Importance, AI is obtained from the sum of multiplication of relative importance with the relationship of each characteristic. Absolute importance gave the information on how the new design should be developed based on Kano Model results. Both absolute results can give clear understanding of prioritizing the technical requirement for ergonomic design improvement process.

$$Absolute\ weight,\ AW = \Sigma\ i \times r \qquad (6)$$

$$Absolute\ importance,\ AI = \Sigma\ j \times r \qquad (7)$$

where; i = user importance
j = adjustment importance
r = relationship rating

The HoQ for designing an ergonomic workstation design improvement was shown in Appendix A. Based on the implementation of the combined methods proposed in this paper, the following results were discovered:

- Malaysian design standard was the most important characteristic to be tackled in order to accomplish user satisfaction, and then followed by comfort criteria. Generally, design standard is following the ergonomic guideline which makes it significantly related to comfort characteristic.
- Less important criteria in technical requirement were material thickness and finishing work which has almost no significant relationship with ergonomics and comfort.
- Safety design and application was the most important quality to the user followed by broad working space.
- On the other hand, adjustable furniture and temporary storage were not so important in user's desirable qualities.

It was discovered that ergonomics was the main factor in engineering characteristic in developing a new or modified product as users nowadays are alert with the importance of safety and ergonomics. Students are interested on safety precaution and cares about their working condition issue. However, adjustable furniture is not favourable by user. Most likely they have never been informed about the importance of correct postures and how to gain benefits from adjustable furniture. A study done by Gerr et al. (2000) indicated that there was no significant different on body pain between those who were using easily adjustable chair than nonadjustable ones. It was possible they may have different postures or they were not given proper instruction on chair use. From user satisfaction values, it was found that users tended to rate all qualities close to neutral satisfaction but more towards important based on user

satisfaction target values. This result was similar to studies presented byChaudha et al. (2011) and Tontini (2007) which indicated that everything is important to user.

3. Conclusion

It was agreed by many researchers that children and adolescents gain major benefits from ergonomic furniture and environment in school (Hänninen and Koskelo, 2003) (Shinn et al., 2002) (Marschall et al., 1995). After intervention, most children preferred ergonomically designed school furniture and workstation (B.Troussier et al., 1999). School furniture problems not only happened in classroom, but also other school facilities may contribute to same problem as the furniture in the classroom. Furniture design should be tailored to students' need and meet their demand. This study was successfully identified and prioritized user and technical requirement to develop a modified workstation of school workshop based on ergonomic approach.

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Appendix A. QFD matrix for workstation design improvement

Desirable qualities		User importance, i	Design: Malaysian Standards	Design: Material thickness	Design: Joining methods	Material: Materials type	Material: Finishing	Material: Weight	Ergonomic: Comfort	Ergonomic: Dimension	Ergonomic: Cost	Kano Category	k value	User satisfaction, u	User satisfaction target, t	Adjustment factor, f	Improvement ratio, R_0	Adjusted improvement ratio, R_1	Adjustment Importance, j
Size	Broad work space	3	5		1			5	3	5	5	O	1	3.94	5	0.58	1.27	2.01	6.03
	Workbench height.	3	5		1			3	5	5	1	1	0	4.17	4	0.43	0.96	0.96	2.88
	Stool/chair height.	3	5		1			3	5	5	1	1	0	4.19	5	0.43	1.19	1.19	3.57
	Adjustable furniture.	1	3					3	5	1	5	1	0	3.67	4	0.38	1.09	1.09	1.09
Design	Additional tools.	3							3		5	1	0	4.00	5	0.47	1.25	1.25	3.75
	Temporary storage	1	1		1			3	3	1	3	1	0	3.66	5	0.24	1.37	1.37	1.37
Comfort	Leg room.	4	5		1				5	5		M	0.5	4.29	5	0.52	1.17	1.44	5.76
	Back rest.	2							5		3	1	0	3.97	5	0.47	1.26	1.26	2.52
	Stable workstation.	4	5	5	5	5	1	5	1	5	3	M	0.5	4.25	5	0.62	1.18	1.50	6
Safety	Smooth working surface.	4	1			5	5		3		1	M	0.5	4.37	5	0.60	1.14	1.44	5.76
	Safety design and application.	5	5	3	3	3	3	3	5	1	5	M	0.5	4.47	5	0.73	1.12	1.47	7.35
Absolute weight, AW			118	35	49	55	39	83	118	92	91								
Absolute importance, AI			168.4	52.1	71.7	80.9	56.9	120.2	161.3	131	133								

Importance scale: 1=less to 5=most importance
Relationship: 1=Weak 3=Moderate 5=Strong