



Redesign of Innovative and Ergonomic College Chair to Improve Student Performance

Hartomo Soewardi¹ Ken Arum Dindadhika²

Industrial Engineering Departement, Faculty of Industrial Technology
Islamic University of Indonesia Yogyakarta

*Corresponding author E-mail: ¹hartomo@uii.ac.id, ²kenarumdindadhika1@gmail.com

Abstract

Poor sitting and an inconvenient change of sitting position during teaching and learning process will inflict the musculoskeletal disorder on several parts of the body beside it may produce some problems for students. One of the problems is decrement of concentration level in apprehending course materials. It can negatively affect student performance. Thus, it is necessary to improve learning, facilities, especially in the form of an innovative chair to accommodate the student's need. This paper presents a study to redesign college chair to be more innovative and ergonomics in order to meet student's requirement. *Kansei* Engineering (KE) method was used to determine the engineering specification of design with mapping process from student's *Kansei*. Anthropometry data was also used to support the design. Statistical analysis was conducted to test the hypothesis. The result of this study showed that a new innovative and ergonomic design of chair was proven to be valid to meet user's need at 5 % of significance level.

Keywords: *Kansei Engineering; Sitting; Ergonomic; Innovative Design; Chair*

1. Introduction

The problem of low back pain caused by sitting is a common phenomenon that often occurs today. There are 60% of adults experiencing lower back pain due to sitting [3]. Longer sitting in an unnatural position can cause the muscles in the waist to become tense and this may also damage the surrounding soft tissues; if this condition continues, it will produce suppression of the spinal cord [32].

[6] conducted a comparative study about the impact of ergonomic and non-ergonomic desk design in three different High Schools. It was found that some students experienced tension at back, neck, shoulders, as well as headache when using non – ergonomic desk. This phenomenon also occurred to students when sitting in a class [32]. Based on preliminary studies, it is known that more than 60% of university students feel uncomfortable when attending a class that it interferes their concentration in learning. This is because of the fact that they should sit for more than two and a half hours such that it effects shifting of sitting position such as sitting with back bending, sitting with neck down, sitting with legs straight out, upright sitting with back sloping to right or left, sitting with one leg crossed over the other, sitting with hands behind the head, sitting by positioning feet under the chair, sitting by putting feet under the front seat, legs crossed right or left, right hand placed on the table, the head is placed on the side of the chair, sitting with the hips not touching the back, sitting with the head tilted to the right, sitting with the hands resting on the table and sitting with the hands folded on his chest. These various sitting positions indicate uncomfortable chair to be used by students during a lecture. This phenomenon shows that the design of chair has not met the user's need in which they require comfortable

chairs that make them easy to freely change their sitting positions. Thus, there is a need to improve the chair design.

Many studies had been done related to furniture design. [28] investigated and impact of postural and chair design upon seat pan interface pressure. This study focused on trunk–thigh angle and use of armrests and found that differences of chair design have effects on seat pan interface pressure. Another study conducted by [33] was an evaluation about the Indonesian National Standard for elementary school furniture based on children's anthropometry and found that there is a mismatch between them. [22] investigated the effect of the feedback signal on sitting behavior and musculoskeletal discomfort. The result of this study showed that 'smart' chair can monitor sitting behavior. In addition, [24] conducted an investigation of skin responses to sustained loading in a sitting position and found that skin barrier changes at the gluteal skin in terms of stratum corneum hydration and transepidermal water loss (TEWL) is caused by sitting on chair with a hard surface.

The objective of the study was to redesign college chair to become more innovative and ergonomics to meet the student's requirement by using the *Kansei* Engineering (KE) method considering human feelings or emotions of users.

2. Literature Review

2.1. Kansei Engineering (KE) Method

Kansei Engineering (KE) is a method that incorporating human feelings [11] and emotions (*Kansei* word) with the engineering discipline to develop a product in order to bring happiness and satisfaction to humans [17].

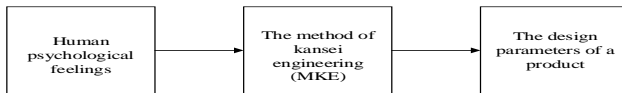


Fig. 1: Diagram of Kansei Engineering Method [11]

KE research began at Hiroshima University in 1970 [10] [12], KE was introduced in Japan to incorporate emotional factors (aesthetics or "Kansei") on product design. Designs that use the mental and emotional satisfaction keep growing and developed with the help of manufacturing companies in the differentiation and positioning of products [34], in recent years much more research about KE has been performed [17] with the result that the KE method developing into various type. It addresses in the table below.

Table 1: Type of KE [13]

Type I	Category classification – Identifying the design elements of the product to be developed, translated from consumer's feelings and image.
Type II	KE System – A computer-aided system with a so-called interference engine and Kansei database.
Type III	Hybrid KE System – The combined computer system or forward kansei, which goes from the user's impressions to design specifications and vice versa.
Type IV	KE Modelling – Mathematical modeling with an interference engine and database
Type V	Virtual KE – An integration of virtual reality technology and KE in a computer system.
Type VI	Collaborative KE Designing- Group work design system utilizing intelligent software and databases over the internet.

KE has been used for new product development as well as for product design [11]. This method has been applied in Japan and has been widely used, especially in locomotive industries such as Miata car output Mazda [14], car setters [15], car interiors [27] [8]. The successful use of KE is the Miata (MX5) product from Mazda. The car product proved favored by consumers to become the best-selling sports car version of the Guinness book of records in 2001 [25]. As the development of the era, KE is widely used in designing various design products such as office chairs [21] and washing machines [7], board games [30], baby bags design [26], lesehan chair design [18] etc.

2.2. Anthropometry Measurement

Anthropometry can be expressed as a study related to the measurement of human body dimensions [31]. The determination of anthropometry dimensions in this research are performed when the Kansei's process number 2 (gathering Kansei word) is completed. Anthropometry data is used to develop a design for height, space, grip, and range for workstations and equipment for the purpose of accommodating the body's dimensions of potential pressure / occupational hazards [29].

In previous research it was found the mismatches between sizes of school furniture and students' anthropometric dimensions have been reported in many countries such as in Greece [19][5], Iran [9][4], Portugal [1] United States [20], India [23] and Chile [2]. The identified mismatch between sizes of school furniture and students' anthropometry carried a negative effect on the students. [19]. Thus, to design a chair in this research it needs the body dimensions such as shoulder seat, shoulder width, sitting elbow height, thigh, popliteal height, hips width, length of down sleeve, popliteal butt, reach of the hand and the body thick.

3. Materials and Methods

3.1. Survey

The paper-based survey is divided into two stages namely preliminary survey and final survey. The preliminary survey is to identify user's Kansei words on attributes of the chair by distributing

questionnaires to more than 100 university students. The final survey is done to test the hypothesis by involving the university students to validate the proposed design.

3.2. Apparatus

Tools used to support research conducted are;

1. Nordic Body Map which a system of measuring complaints of pain in the body known musculoskeletal.
2. Questionnaire for testing the hypothesis and collect the Kansei words
3. Antropometer to measuring the body dimensions
4. IBM SPSS software version 22 that offers advanced statistical analysis.
5. Sketch Up Application Software to design the virtual prototype.

3.3. KE Method to Design

In KE method type 1 there are five steps [17] as follows.

Table 2: Stages of KE Type

Step 1	Identification of target
Step 2	Determination of product concept
Step 3	Breaking down the product concept
Step 4	Deployment to physical design characteristics
Step 5	Translation to technical spesification

3.4. Anthropometry

In Anthropometry, there are various steps as follows.

1. Establish design requirements.
2. Define and describe the user population.
3. Selection of samples to be taken data.
4. Determination of data needs (body dimensions to be taken).
5. Determination of data sources (body dimensions to be taken) and selection of percentiles to be used.
6. Preparation of measuring instruments to be used.
7. Data retrieval.
8. Data processing.
9. Visualize the design.

3.5. Statistical Analysis

After obtaining the Kansei words the validity and reliability should be tested. In the reliability test by using statistical analysis Pearson function to test the coefficient of product moment relation and to test reliability using Cronbach alpha. The non-parametric statistical analysis is used to test the hypothesis to know the difference between old product and new product used marginal homogeneity. To calculate the normality in the body dimensions obtained from anthropometry that is by using Kolmogorov - Smirnov to know the data required dimensions of normal data so that it can be used.

4. Results and Discussion

4.1. Result of Survey

Based on the survey that was conducted in preliminary. It was found 8 Kansei words that presented consumers voices. It was tested by using fault tolerance of 5% as mentioned in Table 3.

Table 3: Kansei words need to break down

Selected Kansei Words	Description	Validity Score	Reliability Score
Comfortable	Provide comfortable design.	0.695	0.805
Innovative Design	Presents comfort with different designs from existing college chairs.	0.730	0.798
Durable	The latest chair design can be used in the long term. The	0.744	0.797
Adjustable	low-height seat can be set so users can feel comfortable.	0.734	0.797
Affordable Prices	The price that can be reached by the customer.	0.414	0.865
Interesting Colors	The chair has a pleasing color to satisfy the user's passion.	0.704	0.806
Safe	Chairs made of a safe and strong material	0.766	0.792
Easy to Move	the latest design has a design that makes it easy to move easily.	0.744	0.797

4.2. Result of Mapping Process for Design

Table 4: Comfortable Mapping Concept

Kansei Word	Sub Concept Level 1	Sub Concept Level 2	Sub Concept Level 3	Sub Concept Level 4	Sub Concept Level 5	Design Specification
Comfortable	Comfortable to used	Comfortable cushion	Size according to body dimension	Dimensions of hip width and popliteal butt		L:52 cm W:43 cm H:6 cm
			Not storing heat	The material used for seat		Material : Foam
			Not smelly	The material used for seat cover		Material : Polyester
			Appropriate shape			Square with curved inside
		Comfortable backrest	Size according to body dimension	Dimension of shoulder width, shoulder height, hip width		L:65 cm W:50 H: 3.5 cm
			Not stiff	Backrest position		Position: 90°- 100°
			Not storing heat	The material used for backrest		Material : Foam
			Not smelly	The material used for backrest cover		Material : Polyester
			Backrest shape			Full back cover
		Comfortable writing table	Flexible to right hand and left hand	Size according to body dimension	Hand reach dimension and field study	L:40 cm W:25 cm H: 2 cm
				Table shape		Rectangle
			Armrest exist	Size according to body dimension	Sitting elbow high dimension	L:25 cm W: 5 cm H: 2 cm

Kansei Word	Sub Concept Level 1	Sub Concept Level 2	Sub Concept Level 3	Sub Concept Level 4	Sub Concept Level 5	Design Specification
				Armrest shape		Rectangle
			Quality material	Material used for table		Material: Wood
				Material used for armrest		Material: Poly Urethane

Table 5: Kansei Word of Comfortable Design in Part



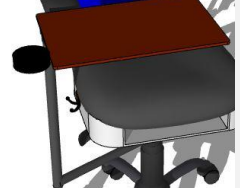



Design Specification	Design explanation
	Chair Cushion
	Backrest
	Comfortable writing table
	Arm- rest

Table 6: Innovative Mapping Concept

Kansei Word	Sub Concept Level 1	Sub Concept Level 2	Sub Concept Level 3	Sub Concept Level 4	Design Specification
Innovative	Innovative design	Facilitate user's entry and exit.	Size according to body dimension	Body thickness dimension	Backrest to table: 27 cm
		Storage rack exist	Size according to body dimension	hip width, popliteal butt, hand reach dimension	L:52 cm W:43 cm H:10 cm
		Drink bottle rack exist	The size of bottle diameter		D: 8 cm H: 5 cm
		Backpack holder exist	Hook shape		Fishing hook shape
			Holder size		L : 4 cm W: 2 cm

Table 7: Kansei Word of Innovative Design in Part

Design Specification	Design explanation
	Entry and exit feature
	Storage rack



Design Spesification	Design explanation
	Bottle rack
	Backpack holder

Table 8: Durability Mapping Concept

Kansei Word	Sub Concept Level 1	Sub Concept Level 2	Sub Concept Level 3	Sub Concept Level 4	Design Spesification
Durability	Durability of chair	Durable pads	Backrest and cushion pads made from quality material	Materials used	Material: Foam
		Durable pads layers	Backrest and cushion pads layers made from quality material	Materials used	Material: Coldore
		Durable outer layers	Backrest and cushion outer layer made from quality material	Materials used	Material: Polyester

Table 9: Adjustable Mapping Concept

Kansei Word	Sub Concept Level 1	Sub Concept Level 2	Sub Concept Level 3	Sub Concept Level 4	Design Spesification
Adjustable	Certain features easy to adjust	Table is easy to change position	Table easy to folded	Folded mode	fold up then sideways
		Cushion height can adjusted according to user's convenience	Height according to body dimension	Popliteal height dimension	H: 38cm – 46cm
		Armrest position can be changed	Type setting		Folded up

Table 10: Affordable Mapping Concept

Kansei Word	Sub Concept Level 1	Sub Concept Level 2	Sub Concept Level 3	Design Spesification
Affordable price	Chair with affordable price	Chair price can be reached by customer	Price option	Rp. 1.000.000

Table 11: Attractive colors Mapping Concept



Kansei Word	Sub Concept Level 1	Sub Concept Level 2	Sub Concept Level 3	Design Spesification
Attractive colors	Chair with appealing colors	Have diverse colors	Cushion color	<p>Gray</p> 
			Backrest color	<p>Blue</p> 

			Table color	Brown  Hue: 20 Red: 70 Sat: 240 Green: 35 Lum: 33 Blue: 0
			Armrest color	Black  Hue: 160 Red: 23 Sat: 0 Green: 23 Lum: 22 Blue: 23



Table 12: Secure Mapping Concept

Kansei Word	Sub Concept Level 1	Sub Concept Level 2	Sub Concept Level 3	Sub Concept Level 4	Design Specification
Secure	Chair from safe material	Frame seats are made of quality materials	Frame seats can withstand heavy weight	Frame shape	Circle and in the middle there is a hole
				Materials used	Iron

Table 13: Easy to Move Mapping Concept

Kansei Word	Sub Concept Level 1	Sub Concept Level 2	Sub Concept Level 3	Sub Concept Level 4	Design Specification
Easy to move	Chair is easy to move	Chair has a large space motion	Chair have hydraulic, mechanical butterfly, star legs, thread wheels		-Hydraulic Small shaft diameter: 2 cm Large shaft diameter: 3 cm Shape: Tube Material: Chrome -Mechanical butterfly Size: 25,5 cm x 15 cm Material: Iron Color: Black -Star legs Length: 28 cm Center hole diameter: 3 cm Material: Nylon Color: Grey -Thread wheels Diameter: 5 cm Material: nylon Color: Grey

Table 14: Kansei Word of Easy to Move Design in Part

Design Spesification	Design explanation
	Hydaraulic shaft
	Mechanical butterfly
	Star legs and Thread wheels

4.3. Result of Mapping Process for Design

The last step is constructing college chair virtually, for overall design is presented on **Fig. 2:**

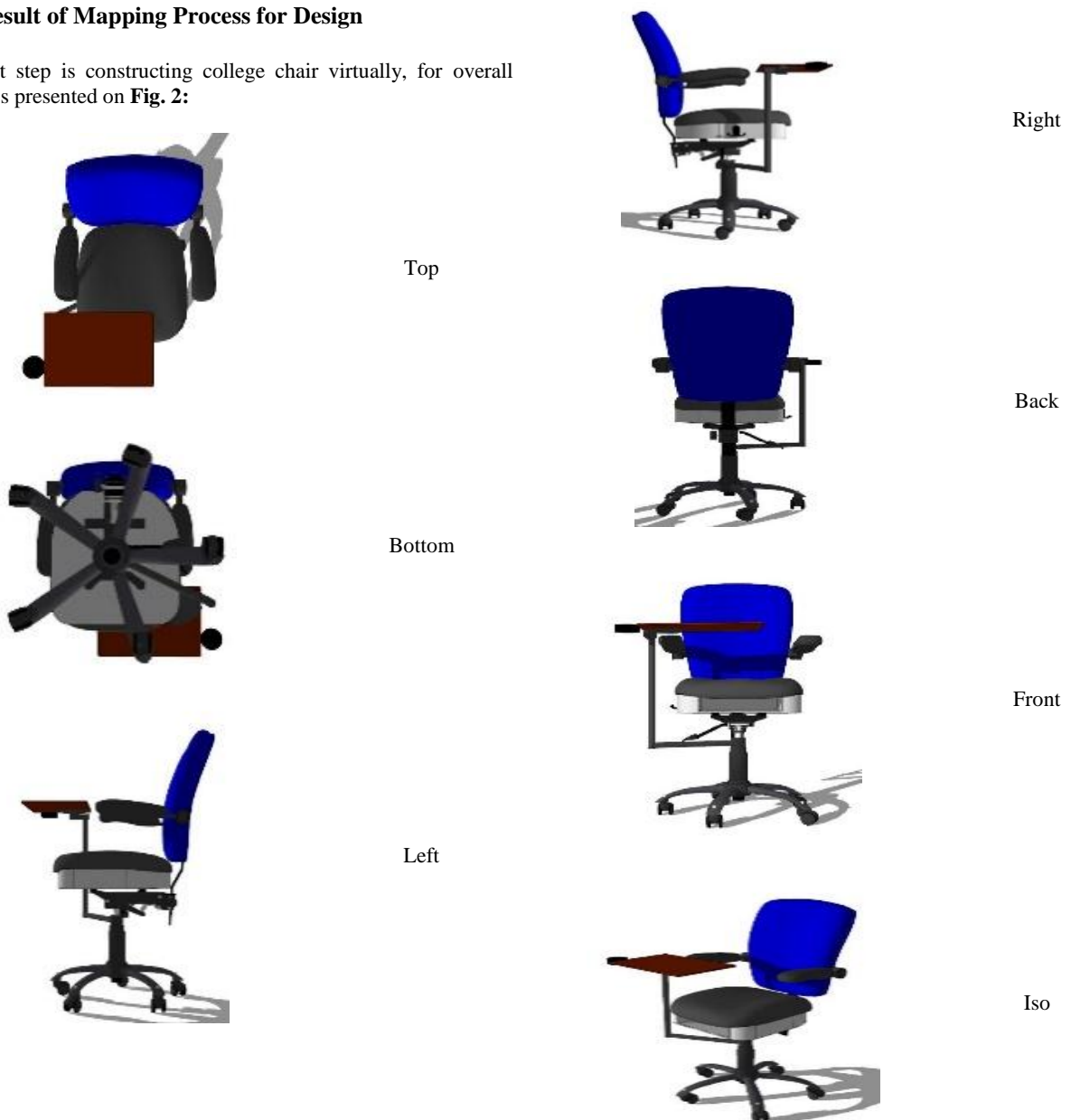


Fig. 2: Virtual Concept Design

4.4. Result of Statistical Analysis

Marginal homogeneity was implemented to test two interrelated samples. The test was on hypotheses whether there was a significant difference between user's requirements and college chair design. The hypotheses were developed as follow:

H_0 : There is no a significant difference between the user's requirements and college chair design

H_1 : There is a significant difference between the user's requirements and college chair design

Table 15: Test of Homogeneity Result

Kansei word	Marginal homogeneity
Comfortable	0.062
Innovative Design	0.345
Durable	0.081
Adjustable	0.301
Affordable Prices	0.129
Interesting Colors	0.201
Secure	0.170
Easy to Move	0.120

Table 15. shows that kansei words of the proposed college chair design is correspond with user requirement at 5% of significance level. It means the proposed design can satisfy what the user looks for.

5. Conclusion

It can be concluded as follows:

1. *Kansei* words that user require from college chair are comfortable, innovative design, durable, adjustable, affordable prices, interesting colors, secure and easy to move.
2. Design specification for comfortable design of college chair are; comfortable cushion with design specification are L: 52 cm, W: 43cm and H: 6 cm. The material for not storing heat is foam and to not make it smelly the material is polyester and the color is gray. For comfortable backrest the design specification are L: 65 cm, W: 50 cm and H: 3.5cm, to make the backrest position is comfortable to user is need a slope in 90°- 100°the material from foam to make it not storing heat and to make it not smelly the material is polyester and the color is dark blue. The design specification for comfortable writing table are L:40 cm, W:25 cm and H: 2 cm material from wood and the color is brown, Armrest design specification are L:25 cm W: 5 cm H: 2 cm, the material is poly urethane and the color are gray. Design spesification for innovative design are; facilitate user's entry and exit with design spesification backrest to table is 27 cm. Storage rack design spesification are L: 52cm, W:43 cm and H: 10 cm and the colour is silver. Drink bottle rack design spesification are D: 8cm and H: 5cm, the colour is black. Backpack holder size is L: 4cm and W: 2cm. The design spesification for durability are; for durable pads the material is from foam, pads layers material is coldore and for the outer layers the material used is polyester. The design spesification for adjustable are; the table is easy to change position so design spesification is to fold up then fold to sideways. Cushion height design spesification are H: 38 cm to 46 cm. Armrest type setting design spesification is folded up. The design spesification for affordable price the price option is Rp. 1.000.000. Design parameter for frame is Circle and in the middle there is a hole, the material is iron. Design parameter for easy to move

are;Hydraulic design spesification for small shaft diameter: 2 cm and large shaft diameter: 3 cm. The shape is tube with chrome as the material. Mechanical butterfly size are L: 25,5 cm and W: 15 cm, the material is iron and the color is black. Star legs design spesification are L: 28 cm, center hole diameter: 3cm, the material is nylon and the color is gray. Thread wheels design spesification are D: 5 cm, the material is nylon and the color is gray.

3. The developed college chair design is valid to satisfy user requirement at 5% of significant level.

6. Acknowledgement

We really grateful because we managed to complete this study. This study cannot be completed without the effort and co – operation from all student Islamic University of Indonesia from participate in filling the questionnaire to support this study.

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