

Conference Paper

Designing Ergonomic Study Chair Using Quality Function Deployment Method with Anthropometry Approach

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Abstract

Increasing the high number of under-fives entering the age of study, commonly called early childhood education (*Pendidikan Anak Usia Dini*--PAUD), creates an opportunity to design a product that supports learning activities for the toddlers, namely folding study desks. This research aims to make a redesign of folding table-chair products specially designed for toddlers by considering ergonomic aspects that prioritize function and comfort using Quality Function Deployment (QFD) method through anthropometry approach of toddler's body. This study focuses on toddlers aged 3 yr to 5 yr who are students of the playing group and kindergarten at Integrated Islamic Kindergarten (*Taman Kanak-kanak Islam Terpadu-TKIT*) "Rabbani". Different body sizes of toddlers with adults are the main consideration in determining anthropometric approach, but it is also expected to produce ergonomic products both in terms of materials and product size to a child's sitting position. The results of this study obtained a comfortable chair table, soft and comfortable backrest, strong seat resistance, comfortable padded seat cushion, has a place to store bag/footrest, has a place to store stationery, has an attractive color and seats safe to use, and has additional features for gadget. As for the changes made in terms of the dimensions of the chair that prioritize ergonomic values, the seat height is 60 mm, the back height is 33.2 mm, the width of the backrest is 30 mm, the length of the seat is 26.6 mm, and the seat width is 26.6 mm. All these additions are additional tolerance for comfort, especially for large children.

Keywords: Ergonomic product design; quality function deployment; toddler study chair design

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1. Introduction

The world of children is a world full of joy, great curiosity and high enthusiasm. Children under 5 yr, are the most enjoyable times and are still filled with games, so the learning process adapts to the child's needs to feel happy and interested in the lessons learned. On that basis, in the learning process, for toddlers not merely sitting still on a chair and working on the questions on the table like elementary students, all the lessons are given interactively through several games.

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Learning tables and chairs are a supporting tool in the teaching and learning process for students of playgroups and kindergartens. Generally, the existing study tables and chairs are separate tables and chairs made of heavy and rigid material. This is a bit difficult for teachers because they have to move tables and chairs if the children start running during lessons and heavy materials. The high mobility of students and teachers during the lesson so that they need flexible chairs to be taken and moved wherever that is the main consideration of this research. The form of a stiff chair table also has the effect of easy fatigue, boredom and pain in the waist if it takes too long to do the task, so an ergonomic chair that supports the child's body shape is needed.

Based on the problems described above, it is known that the desk chairs used in schools are still very simple and not ergonomic. Thus, this study aims to design folding learning tables that are easy to move anywhere but still adjust the child's body shape so as to provide comfort for children when using it.

Comfort is an absolute requirement that is sought by every consumer and is a major concern for every innovator engaged in the field of human comfort. Consumers are generally willing to pay more for a product that in fact provides comfort to the user when using it. For this reason, it is hoped that this design will become a prototype for folding study chairs that are comfortable, relaxed, easy to carry anywhere and can be mass-produced.

To find out more deeply what are the hopes, desires, which can provide satisfaction for consumers, a questionnaire is distributed to parents and student teachers as stakeholders for the needs of this product. Because end users of this product are children under 5 yr who generally have not been fluent in reading and writing, then their opinions about comfort are considered capable of being represented by their parents and teachers. Using the results of the questionnaire analysis will be designed ergonomic folding learning tables. Ergonomic evaluation should be done to measure the comfort level of respondents with anthropometry feasibility. Anthropometry is a value or collection of numbers related to the characteristics of the human body, size, shape and strength and the use of data on the design problems encountered.

In general, the description of the product to be made is folding study tables with the aim of saving space and facilitating the process of space management. The added value of this product is the addition of features in the form of whiteboard tables that can be written and erased easily using blunt pencils that blend with the table and mini tabs that function as children's entertainment media.

Based on the background above, some problems can be identified, such as the following, first, no created folding portable learning tables with reference to the child's

body anthropometry data have been developed, second, the existing study tables and chairs do not pay attention to the user's comfort, especially in terms of ergonomics, and the third, the unfinished learning folding tables for early childhood education (*Pendidikan Anak Usia Dini--PAUD*) students that suitable with customer needs and in accordance with the opinions of experts (teachers and parents). In this paper, research is focused on table-chairs for toddlers aged 3 yr to 5 yr, second, measurement of parameters using the Quality Function Deployment method with the child's body anthropometry approach and the third retrieval of respondent data devoted to students at "Rabbani" Kindergarten at the Marcellia Park Housing, Batam Center, Indonesia; for the results to be used at the school.

2. Literature review and hypothesis

2.1. Product design and development

The definition of product design and development is a series of activities ranging from analysis of market perceptions and opportunities, to the stages of production, sales and product delivery [1]. In the product development process, we need to determine the problem statement. The statement will include consumer desires, added value or benefits obtained by consumers, as well as other relevant information. The statement of this problem can later be updated in accordance with technological developments and people's lifestyles [2].

There are at least five stages needed during the process of developing new products, namely the generalization of ideas, planning and concept development, product development, prototype development and testing processes, as well as the production process and introducing products to the market [3].

The product design process must go through several stages to produce a product; the process is:

2.1.1. Identify customer needs

The process of identifying customer needs is obtained from the House of Quality (HOQ) matrix that has been carried out in the previous stage, from this process it will be known how the customer needs for a product, so that the need is a valuable input for the design of a product.

2.1.2. Product specifications

Customer needs are generally expressed as "customer discussion". To provide specific demands on how to design and make a product, a set of specifications is specified. This specification will explain details about the things that the product must do to obtain commercial success. This specification must also be able to reflect customer needs, differentiate products from competing product products and can be technically and economically realized.

2.1.3. Formulation of product design concepts

The product concept is an illustration or estimate of technology, working principles, and product form. The product concept is a brief description of how products satisfy customer needs. A concept is usually expressed into a sketch or a 3-dimensional model outline and is often accompanied by a description of the picture. A product can satisfy customers and can be successful in the market depending on high value for the quality measures that underlie the concept. Drafting the concept begins with a series of customer needs and target specifications (based on predetermined target values) and ends with the creation of several product concepts as the final choice.

2.1.4. Selection of product design concepts

Concept selection is the process of assessing concepts by paying attention to customer needs and other criteria, comparing the relative strengths and weaknesses of the concept, and choosing one or more concepts for further investigation, testing and development.

Product development projects are grouped into four types [1] that is:

1. New product platform, this type of project involves a major development effort to design a new product family based on a new and common platform.
2. The derivative of the existing product platform, where the project extends the product platform so that it is better to enter a market that has been known for one or more new products.
3. Improved improvements to existing products, this project may only involve the addition or modification of some product details from existing ones in order to maintain a competing product line.

4. Basically, a new product, that is, this project involves a very different product or production technology and may help to enter an unknown and new market.

2.2. Anthropometry

By definition, anthropometry can be expressed as a study relating to the measurement of dimensions of human body. Humans basically have different shapes, sizes, weights [4]. Ergonomists generally carry out several stages in designing a product based on anthropometric principles, including: (i) defining the population to be designed, (ii) determining tolerance of critical body size, (iii) choosing a percentage of the population to be measured, (iv) determine anthropometric principles (range, extremes, and averages), (v) allocate data in tabular form, (vi) adjust to body posture, (vi) conduct tests [5].

The principles that must be taken in the application of anthropometric data include:

1. The principle of designing products for extreme individuals; divided into two, namely the largest individual-based design (the largest anthropometric data), and the second is the smallest individual-based design (the smallest anthropometric data).
2. Principles for designing facilities that can be adjusted; usually used to design a facility so that it can accommodate or be used comfortably and comfortably by all people who might need it.
3. The principle of designing products that are operated within a certain size range; used if the two previous principles are not possible.

Anthropometric data used as a basis for product design are generally grouped into two types, namely:

2.2.1. Structural Data

Is a measure of the body dimension of a subject who is in a static position. Measurements are made from one clear point to another, such as measuring height from floor to head.

2.2.2. Functional Data

An anthropometric data collected to explain the movement of body parts at a pre-determined point. The maximum hand forward data from the standing position of the measured subject is an example of functional anthropometry data.

2.3. Sitting posture

The purpose of a seat is to support a stable posture by considering the comfort of use for a long time, psychological satisfaction and compatibility with the activities carried out using the product. The comfort referred to here is related to the activities carried out by the user when sitting. That is why there are three factors that greatly affect comfort, including: the character of the seat, the character of the user, and the character of the job [6].

Sitting posture was first introduced in 1884 as "hygienic sitting postures" by Staffel who recommended an upright sitting posture on the neck, back and head with normal lordosis in the lumbar and cervix conditions and mild kyphosis in the thoracic spine. resembles a spinal posture when standing upright. Upright sitting posture is a static sitting posture, contrary to the changing characteristics of the human body. Upright sitting posture for a long time can cause discomfort in the spine at risk of suppressing the soft and vulnerable parts of the spine, reducing metabolism, deficiency in blood circulation, and accumulation of extracellular fluid in the lower leg [7].

2.4. Ergonomic

Ergonomics is a systematic branch of knowledge to utilize information about the nature, abilities and limitations of humans to design a working system, so that humans can live and work on the system properly, namely achieving the desired goals through the work effectively, safely, and comfortable. In general, there are two main objectives of ergonomic studies, namely i) improving the reliability, efficiency, and productivity of humans in carrying out their work by improving the quality of interaction between humans and other work environment components while minimizing the level of human error; ii) improve work safety, reduce fatigue and mental tension and improve work comfort.

The main value to be achieved from the evaluation of ergonomics in the design process is to prioritize human interests so that they can be included in every creativity and innovation of a man-made product [4]. The main focus of ergonomic studies is the fulfilment of the requirements of "fitting the task to the man" that every product design must consider in terms of safety, health, safety and comfort. In additions, the design should carry out evaluation/testing/research concerning functional technical, as well as other economic feasibility. Ergonomic is currently the one that determines the direction of technology, unlike in the past where ergonomics is still governed by technology [8].

2.5. Quality function deployment

Quality function deployment is a structured method of planning and product/service development that allows the development team to clearly define consumer needs and expectations and evaluate the ability of the product/service systematically to meet those needs and expectations. QFD was originally developed from Japanese expression, namely Hin Shitsu which means quality, Ki No which means function or mechanism, and Ten Kai which means dissemination or development [9].

According to [10], QFD applications are limited by one's imagination. The basic purpose of QFD is to encourage product developers with systematic methods to spread the voice of the customer into product design, so that entrepreneurs are able to evaluate potential responses in the face of universal customer needs and desires. This is important because almost all organizations (businesses) face competition. There are three main benefits when a company uses QFD, namely reducing costs, increasing revenue, and reducing production time. The QFD process itself starts from hearing the voice of customers through various media and then continues through three main activities, namely product planning, product design, and process planning control.

3. Conceptual models

This research works deeper into what customers really want that can provide value added products compared to products that are already on the market today. Hopefully this research will provide great satisfaction for customers so that later not only the school can use this product design, but can be used in all PAUD schools in Batam islands. It can be concluded that it is true that there is a close relationship between the desires of customers, customer interests and customer satisfaction with the final results of the design form of folding study chairs in this study. If it is made in the form of an associative hypothesis, it can be described as follows:

H1: Customer wishes affect the Product Design

H2: Customer interests affect the Product Design

H3: Customer satisfaction affects the Product Design

H4: Customer Desires, Customer Interests, and Customer Satisfaction together influence the Product Design

To facilitate the understanding of the formulation of hypothesis obtained, it can be seen in the research diagram shown in Figure 1:

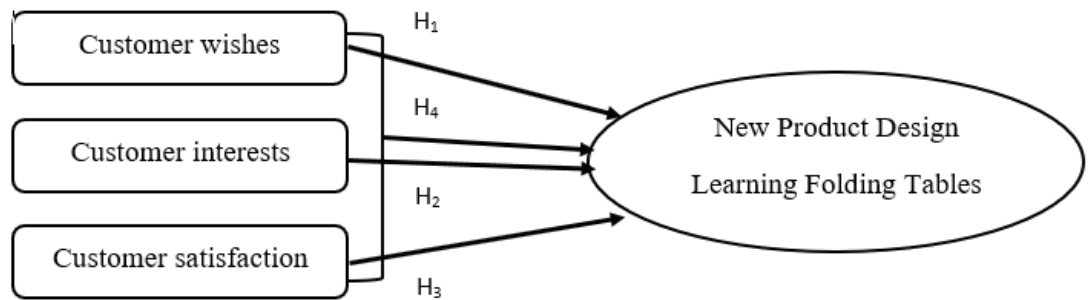


Figure 1: Research hypothesis scheme.

4. Research method

4.1. Research sites

This research took place at PAUD school named TKIT (Integrated Islamic Kindergarten) "Rabbani" which had been established since nine years ago, located in Baitul Amal Mosque Complex, Perum Marchelia, Batam, Riau Islands, Indonesia.

4.2. Population and sample

The school has three classes, namely Playgroup, Kindergarten Level A, and Kindergarten level B. The total student population is around 70 students, and because of the relatively small amount it is decided to examine the entire population in data sampling.

4.3. Data collection technique

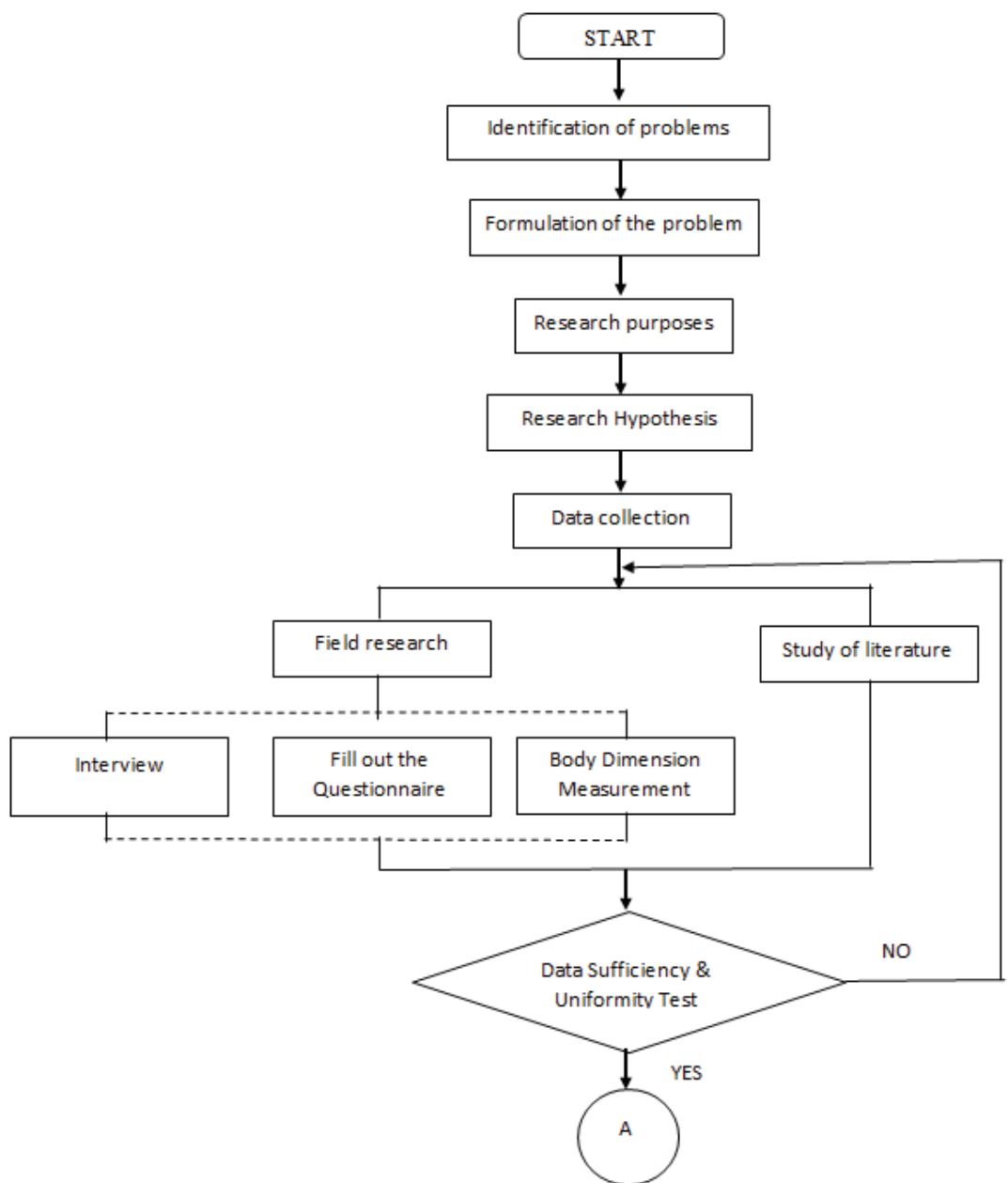
Data collection techniques in this study use data collection methods such as the following:

1. Field research, namely research conducted by observing/interacting directly with respondents, as for the methods, among others:
 - a) Direct measurement of all students studying at the school, to find out data on dimensions of student body size.
 - b) Distributing questionnaires to stakeholders, namely teachers and parents, this is done because PAUD students generally have not been fluent in reading and writing so it is feared that they can make the results of the questionnaire invalid.

2. Library research (library research) which is a literature study that has a close connection with the issues discussed.

4.4. Data collection technique

The research model used is naturalistic namely the implementation of research that occurs naturally, as is, in normal situations that are not manipulated by the conditions and conditions. The stages of this research can be seen in Figure 2:



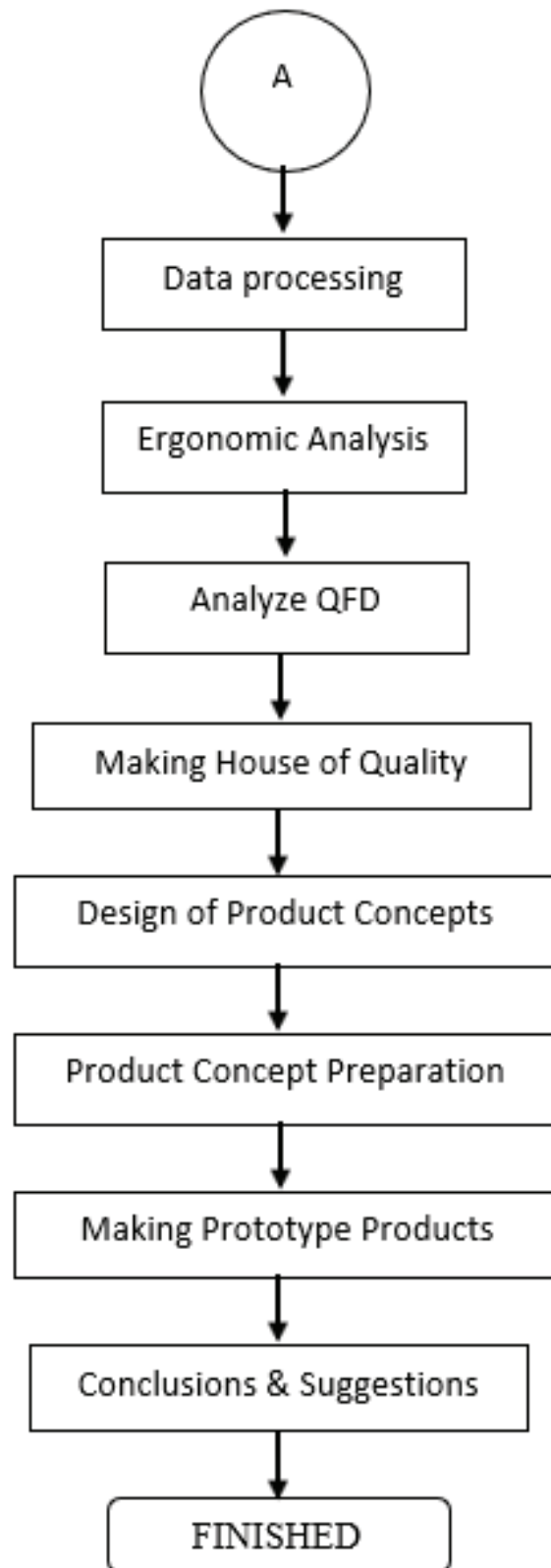


Figure 2: Research model flow scheme.

5. Finding

Based on the results of the measurement of anthropometric data conducted on PAUD students at TKIT "Rabbani" who are generally 4 yr to 6 yr, the results are obtained in Table 1.

TABLE 1: Anthropometric mean child dimension measurement data.

No	Anthropometric Dimension	Average (mm)
1.	High sitting upright	335
2.	Shoulder height sitting	253
3.	Elbow sitting	125
4.	Backrest	210
5.	Shoulder width	280
6.	Width / thigh thickness	110
7.	Thigh length	323
8.	Knee height	315
9.	Thick stomach	145
10.	Hip width	267
11.	Upper arm length	170
12.	Elbow length	265
13.	Pelvic height	132
14.	Long range hands forward	448

The research variables used in preparing the questionnaire can be seen in Table 2.

From the results of processing the data taken from the questionnaire distribution, it was found that the level of consumer interest for designing toddler folding chair tables as shown in Table 3.

6. Discussion

6.1. Designing house of quality (HOQ)

Figure 3 are the results of data processing in the form of quality home images and weighting tables that state their importance.

TABLE 2: Research variables on the children's folding table desk questionnaire

No.	Factors Affecting Consumer Satisfaction
1.	Functional Products
	i. Light
	ii. Save Place
	iii. Easy to move
	iv. Strong withstand heavy loads
	v. Easy to clean
	vi. Additional features/accessories
2.	Product Safety
	i. There is no sharp side
	ii. There is no angle
	iii. Not easily shaken
3.	Product Life Cycle
	i. Durability level
	ii. Resistant to rust and rust
	iii. Lack of care
4.	Product Material
	i. The backrest and seat are soft and soft
	ii. The backrest and seat holder are foam coated
	iii. Child friendly
	iv. 4. Interesting final finish
5.	Product Aesthetics
	i. Attractive / modern product design
	ii. Bright color variations
	iii. Motif of backrest with cartoon images
6.	Ergonomic (Leisure) Products
	i. Dimensions of the backrest according to the dimensions of the child's back
	ii. The shape of the chair backrest must be upright
	iii. The distance between tables and chairs that conform to the standards of comfort in reading / writing
	iv. There is an armrest
	v. The level of footing needs
7.	Economical Products
	i. Prices that compete with similar products
	ii. Special prices for educational institutions, especially PAUD

TABLE 3: Product Design Interest

No.	Variable	Level of importance
1.	Lightweight material, easy to move	5
2.	Space saving	4
3.	Easy to clean	4
4.	Load-bearing strength	5
5.	Easy to fold	4
6.	There are no sharp corners and sides	4
7.	Child-friendly material selection	4
8.	Durable and long lasting	5
9.	Attractive design	4
10.	Selection of attractive colors and motifs	4
11.	Product dimensions that are suitable for children's anthropometry size	5
12.	Ergonomic backrest	5
13.	Ergonomic armrest	5
14.	Ergonomic seat holder	5
15.	Competitive prices and discounts for educational institutions	4
16.	Add Tab features on the table	3
17.	Adding stationery storage features	3
18.	Additional footrests	3

6.2. Determination of product characteristics

Based on the results of the measurement of interests summarized in the House of Quality (HOQ), it was decided to select the product characteristics in detail described as follows:

6.2.1. Raw Material

There are four product parts that will be explained by the type of material selection, among others:

1. For selected chair frames, iron which has strong material, is easy to apply and in terms of financing, including the cheapest when compared to other selected raw materials such as stainless steel, aluminum and steel.

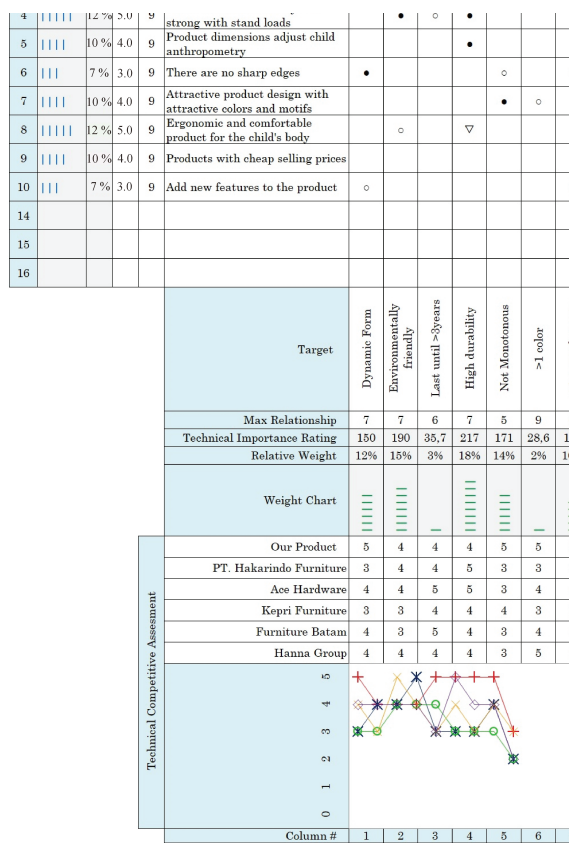


Figure 3: House of quality design of learning folding chair tables.

- For table parts, the choice of falling into plastic or acrylic is lighter than plastic PVC. This is done to prevent instability due to too much weight on the table, so that the chair cannot support it.
- For the backrest part and seat support, the holder still uses plywood made from wood powder, to ease the burden, cheap financing and durable. As for the foam

backrest and seat holder, type 24 foam is chosen which has a more elastic density and minimalist price. For coating material, the outer part of the backrest and seat is used suede and microfiber which is easy to absorb oil and in terms of very economical prices.

4. There are several additional facilities that have never existed in toddler learning chairs generally, namely footrests, place of stationery and tab features. For footrests use the same iron as the seat frame but are made in such a way as to be able to be used as a storage bag for student bags. The place of stationery and tab features are modified when printing a plastic table, with reference to the product design that has been clearly described.

6.2.2. Product Dimensions

Data containing the dimensions of body dimensions or anthropometry of the entire population (students). The data does not pass the data uniformity test and data adequacy test, because this study has recorded the entire population data rather than just taking samples. The percentile values of each data are described as in Table 4.

TABLE 4: Percentile Calculation Results Data

No.	Anthropometric Dimension	Percentile (mm)		
		P5	P50	P90
1.	High sitting upright	324	335	340
2.	Shoulder height sitting	242	253	255
3.	Elbow sitting	116	125	130
4.	Backrest	204	210	215
5.	Shoulder width	269	280	285
6.	Width / thigh thickness	103	110	115
7.	Thigh length	316	323	330
8.	Knee height	307	315	320
9.	Thick stomach	136	145	150
10.	Hip width	255	267	272
11.	Upper arm length	160	170	175
12.	Elbow length	256	265	270
13.	Pelvic height	127	132	137
14.	Long range hands forward	439	448	453

6.2.3. Color Selection

Generally, student learning chairs only have one color, but in the design of this product, three bright colors are red, yellow and green. This is done to emphasize the bright, cheerful and diverse character of PAUD students.

6.3. Ergonomic learning folding chair table design

Referring to the results of measurements of toddler body anthropometry data, it was obtained the size of ergonomic study folding chair table design as shown in Table 5:

TABLE 5: Ergonomic product design dimensions.

No.	Product Part Description	Percentile	Dimensions (mm)
1.	Seat height	P-90	600
2.	Seat back height	P-50	332
3.	The seat back width	P-90	300
4.	The distance between the chair back of the chair table	P-90	173
5.	Seat holder length	P-90	26.6
6.	Seat width	P-50	26.6
7.	The distance between the table from the seat holder	P-50	158
8.	Table length	P-5	420
9.	Table width	P-5	300
10.	Armrest length	P-50	198

6.4. Comparison of characteristics of old and new products

After obtaining dimensions for new products that prioritize ergonomic values, a comparison of the characteristics of the old products and new products is carried out so that it can be seen in terms of innovations carried out in this study, as seen in Table 6:

TABLE 6: Comparison of old and new product design.

No.	Dimension Name	Anthropometric Dimension (cm)		Information
		Initial	End	
1.	Seat height	55	60	The addition of chair height as tolerance for children who have a high body

No.	Dimension Name	Anthropometric Dimension (cm)		Information
2.	Seat back height	26	33.2	Increasing the height of the chair back to provide comfort tolerance for moving
3.	The seat back width	29	30	Increasing the width of the chair back to tolerate the child while playing
4.	The distance between the chair back of the chair table	Depends on Seat Users	22	Standardized size, will facilitate the arrangement of the room using this product
5.	Seat holder length	25	26.6	Size addition to provide additional comfort tolerance especially for large children
6.	Seat width	25	26.6	Size addition to provide additional comfort tolerance especially for large children
7.	The distance between the table from the seat holder	19	20	Size minimization to ensure that the position between table and chair is very appropriate for the learning process
8.	Table length	114	33.2	Minimize size for easy transfer of goods
9.	Table width	114	30	Minimize size for easy transfer of goods
10.	Armrest length	None	23.5	Being one of the advantages of this product design
11.	Footrest	None	There is	Being one of the advantages of this product design
12.	Place of Stationery on the Desk	None	There is	Being one of the advantages of this product design
13.	Accessories Tab	None	There is	Being one of the advantages of this product design
14.	Table Raw Material	Polyvinyl chloride (PVC) plastic	Acrylic or Plastic	The selection of plastic as a consideration not to burden the chair frame so that it remains stable even with heavy loads
15.	Seat Frame Material	High density polyethylene (HDPE)/polypropylene (PP) plastic	Iron	Selection of iron to make it sturdy and durable
16.	Material Seat Base	None	Type 24 (5 cm)	A type of foam that is solid and chewy for the convenience of students
17.	Chair Backrest Material	None	Type 24 (5 cm)	A type of foam that is solid and chewy for the convenience of students
18.	Coating material	None	Suede and Microfibre	The addition of coating material to add comfort to the sitting position
19.	Color	one color	Multiple Colors	Color enhancement to enhance student learning spirit

6.5. Final draft drawing

The final step of this research is the making of a final drawing of a folding chair study table for toddlers in three dimensions can be seen in the Figure 4.

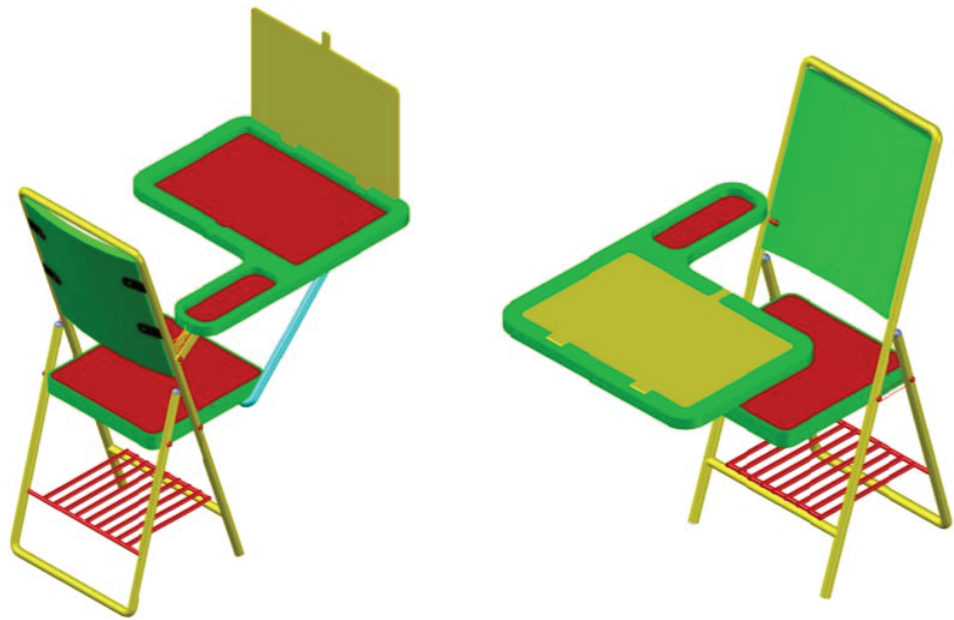


Figure 4: Final design results of folding learning tables.

7. Conclusion

7.1. Conclusions

The conclusions that can be drawn from the results of this study include:

1. The process of designing this product begins with the collection of the child's body anthropometry data, then calculates the percentile value of each dimension. The next process is by collecting questionnaire data which will be used as the basis for the preparation of the level of importance of product design. After that, the House of Quality was designed to be a reference in determining product characteristics. After all of the data is complete, the researcher designs the physical form of the product in three dimensional form.
2. To facilitate the preparation of the level of interest and customer satisfaction towards product design, it is concluded that there are seven main factors that will influence consumers' desire to buy products, among others: functional products,

product safety, product life cycle, product material, product aesthetics, ergonomics (comfort) products, and economic products.

3. The final design of the study folding chair table product devoted to PAUD students is very ergonomic and prioritizes the child's body anthropometry. As for the use of chair frame material, iron materials and plastic materials for table raw materials are chosen. To emphasize the ergonomic aspect, the backrest and seat holder are made from foam with suede coating to make it easy to clean. The addition of features which is the added value of this product is adjusted to its main function as a medium of student learning.

7.2. Suggestions

From the results of this study, there are several suggestions that can be given, among others:

1. For the design of similar products in the future, it will be better if you take into account the estimated time and costs needed until the design of the product can be realized perfectly.
2. In the next design, it is expected to conduct a product failure analysis as feedback on the product development process.
3. If anyone want to do the design of a similar product, it is expected to be able to be carried out completely to the prototype making process, which certainly requires a strong commitment from the funders.

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