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Developing an electric keyboard cleaner as an innovative alternative design

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ABSTRACT

It is crucial to maintain cleanliness on our desks and portable tools, such as computers, to prevent dust and other debris accumulation. This practice is essential for uninterrupted usage and to avoid expensive repair costs. A dusty keyboard, with debris lodged between the keys, can significantly disrupt work, hinder keyboard performance, and necessitate time-consuming cleaning. Dust accumulation poses the risk of damaging computer components. Regular computer cleaning ensures optimal and seamless functionality. This research details the development of a portable keyboard cleaner, presenting an innovative design aimed at removing dust and dirt from computers and laptops. The industrial design concept employs the Quality Function Deployment (QFD) method. The process begins with a questionnaire stage to gather customer needs, followed by material selection, consideration of anthropometric data, fabrication, and testing. The manufacturing process utilizes 3D manufacturing for the main components. Final testing involves directly cleaning a laptop keyboard to verify the tool's effectiveness. The research results have led to a product meeting customer needs as per the questionnaire, addressing aspects like ergonomics, materials, durability, safety, cost, among others. The study also recommends an affordable price range, considering estimated returns on investment, anticipating a favorable reception in the market.

1. Introduction

Online learning emerged as the chosen alternative in the education sector during the Covid-19 pandemic to sustain the teaching and learning process, paralleling the transition of office work to online platforms [1], [2]. The pandemic instigated numerous lifestyle changes, enforcing various restrictions to ensure the safety of communities, including limitations on gatherings such as schools and offices. A study from Korea identified five dominant themes that surfaced during this period: shifts in daily routines, health practices, familial dynamics, social connections, and community engagement [3]. Many students find online learning methods highly beneficial, deeming them effective with observable progress [4].

The era of online learning calls for continuous technological enhancement to streamline the online education system [3]. Devices like laptops and Personal Computers (PCs) are pivotal, facilitating numerous virtual activities. Work environment conditions significantly impact productivity, performance, and comfort. In 2022, Kawakubo and Arata [5] concluded that productivity levels significantly increase when work is conducted from home. Maintaining the cleanliness of workspaces, including computers (especially keyboards), is imperative for safety, health, and the durability of equipment. Research indicates that electronic devices and keyboards exhibit the highest contamination rates [6].

The keyboard, known as the human interface device, stands as a crucial component within a computer system. Identifying prevalent issues associated with keyboards forms the basis for designing appropriate care and cleaning products, essential to prevent malfunctions and maintain their full functionality. Maintaining a laptop keyboard is not only pivotal for preserving equipment in optimal condition but also for extending its lifespan, eventually saving money. Consistent keyboard cleaning, rather than infrequent deep cleaning, demands less time and effort. Regrettably, work demands, or assignment pressures often lead users to neglect their computer's cleanliness, particularly the keyboard area. Moreover, exercising caution during key cleaning is crucial to prevent damage or removal of markings on keys [3]. Using specialized keyboard cleaners proves preferable, effectively removing dirt and dust lodged between buttons.

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However, increased busyness and workloads can lead to a decline in health standards. Keyboard cleaning products, tailored to meet customer needs, have been designed to address these issues. The design concept encompasses all aspects according to industrial design principles to fulfill customer requirements [3]. In this modern era, the use of social media assists researchers in understanding customer needs [7]. To ensure customer satisfaction, the company has fostered deeper relationships with its customers [8].

The cleanliness of keyboards and maintaining their condition form the basis for researchers to take the initiative to design a tool usable as a keyboard cleaner. This product offers an alternative among other options suitable for all levels, from students and employees to the public. Commercial aspects such as comfort and convenience will be prioritized. Therefore, product design should consider materials and comfort. Utilizing high-quality materials will enhance the product experience [9].

Multi-criteria decision-making involves various methods, each offering different results based on its approach [10]. Despite the availability of numerous methods for selecting product materials, the researchers have chosen the tabular additive method. Several materials will be studied in this research. The survey has been conducted with respondents for the community level from students, employees, and the public. The target observed on this research was male and female who actively using laptop or computer with the range of age around 7 until 55 years old. The scope of this project is to design, manufacture and testing the Electric Keyboard Cleaner.

Several previous journals have conducted research related to product design motivation and the incorporation of 3D printing in prototype manufacturing, such as [11], which emphasizes the importance of the design concept process to achieve results aligned with the objectives [12]. Another study provides insights into the utilization of 3D printing in prototype creation, outlining both strengths and associated costs in the production phase. Moreover, [13] highlights 3D printing as an initial step before addressing intricate component production issues, minimizing potential losses due to production failures. These three journals serve as valuable references for creating effective design concepts for an advanced electrical keyboard cleaner and developing intricate prototypes through 3D printing [14].

The objective of this research is to design and develop a product that meets the needs of a diverse user base. Additionally, this study aims to introduce an innovative keyboard cleaning tool suitable for users across all levels, based on market surveys. This research aligns with the increased use of laptops for online activities and delineates the design and implementation processes involved in creating the Electric Keyboard Cleaner according to customer needs.

Building upon the earlier paragraphs, this research makes a significant contribution to ergonomic concerns, particularly in ensuring users' comfort and enhancing productivity. Ergonomics serves as a preventive measure against awkward postures, extreme temperatures, and repetitive movements. Moreover, it can alleviate users' fatigue and stress, both physical and psychological factors contributing to absenteeism.

2. Material and method

2.1. Problem formulation

In this research, one of the methods employed for data collection was the use of questionnaires. With specific considerations in mind, the researchers designed fifteen questions to inquire about the users' needs. These questionnaires were instrumental in conducting an in-depth analysis of customer requirements. Additionally, the researchers sought to understand the detailed use of the keyboard and identify potential competitors. Furthermore, six out of the fifteen questions served as a validation of our questionnaire.

The questionnaires have been distributed by spreading the Google form link. In total, the researchers received about 36 respondents for the questionnaire. Some of the respondents are being accompanied by the researchers while fulfilling the questionnaire. Within the discussion, the researchers also received a deep understanding about the design that customer need. It needs the specific recommendations regarding to critical element on the data quality that contained on the scientific manuscript [13].

As the result of the questionnaire, 41,7% of the respondents were students where about 58,3% of the respondents were the workers. Those fifteen questions on the questionnaires aim to determine the customer needs. This research also calculates the validity and reliability level on the questionnaire by using SPSS Software. Validity was used to calculate the accuracy of an instrument in measuring. Reliability was often used in the process of calculating the consistency of measuring instruments, this measurement was done to ensure the level of accuracy and reliability of the tool if re-measurement needs to be done [15].

The researchers use Bivariate Pearson on the SPSS Software. the instrument or question item can be said to have a significant correlation with the total score if the calculation result R is greater than the table R (a 2-sided test with a sig. 0.05). This condition means that they can be categorized as valid data. For the 36 respondents, R count was 0.279. As it shown the Table A1 (see Appendices), all the R table value was higher that its R count. It can be concluded that all the variables were valid and stated that if the value of ρ is positive, there is a directly proportional relationship between the variables; means if ρ = 1, the correlation has a perfect positive linear correlation. As it is concluded that the data are valid, then the researchers also conducting the reliability test on the data. The data can be categorized as the reliable when the value of Cronbach's Alpha is more than 0.6 [16]. The result of SPSS proved that the data are reliable within 0.610 of Cronbach's Alpha value on Table A1.

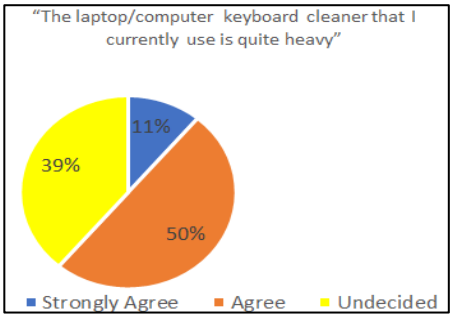

Figure 1. Results question #7

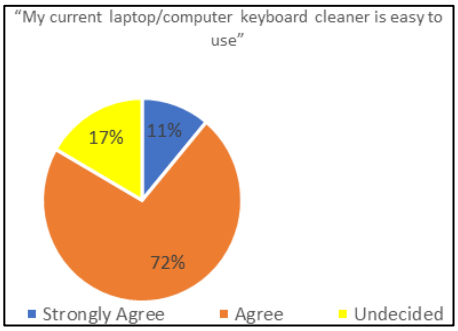

Figure 2. Results for question #8

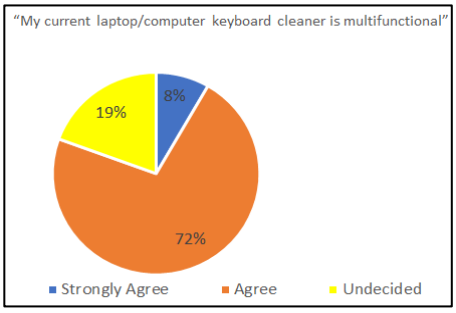

Figure 3. Results for question #9

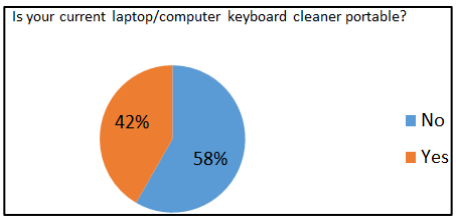

Figure 4. Results for question #10

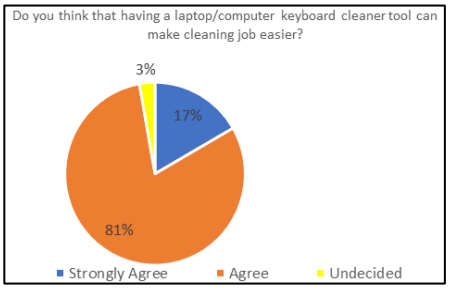

Figure 5. Results for question #11

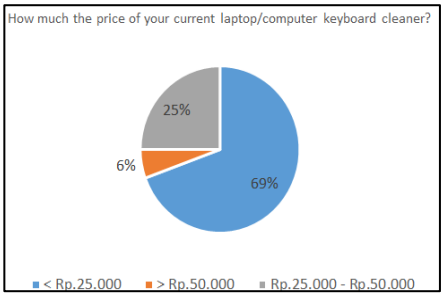

Figure 6. Results for question #12

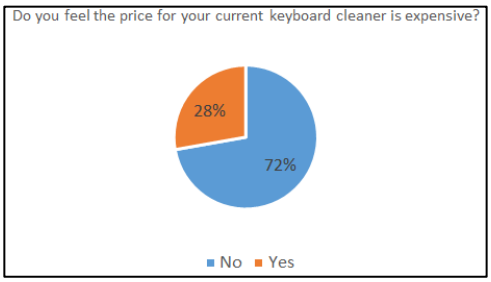

Figure 7. Results for question #13

Based on questions as mentioned in questionnaires, the researchers received five customer needs such as:

1. Lightweight. This kind of need comes from question number #7. On that kind of question, the researchers need to know about the tool's weight. From Fig. 1 as the result of the discussion, the respondents prefer to have a lightweight tool to prevent fatigue and make the cleaning activity become easier.
2. Easy to Use. Question #8 has represented the need for an easy-to-use tool. In this question, 26 respondents have agreed that the cleaner tool must be easy-to-use, so the respondents can maximize the cleaning result and minimize the time for installing the tool before it is used as shown in Fig. 2.
3. Multifunctional Tool. Fig. 3 shows the result of Question #9, this term can be one of the customers' needs to design the cleaner tool. Hopefully, the tool is not only focusing on cleaning the keyboard but also has other functions.
4. Portable Tool. Based on Question #10 as shown in Fig. 4, it can be concluded that the customer wants a portable tool, because they think that portable tool is easy to carry everywhere.
5. Ergonomic Design. Question #11 has represented the needs of ergonomic design and automatic tools as shown in Fig. 5.
6. Affordable Price. Both Questions #12 and #13 are related to the price that the customer wants on a keyboard cleaner tool as depicted in Fig. 6. Question #13 shown, they hope that it will be useful and still on the affordable and reasonable price as shown in Fig. 7.

2.2. *Quality Function Deployment*

The primary foundation for product design is Quality Functional Deployment (QFD). By using the

QFD methodology, this study ensure that output—whether it's a product or a process—will meet the needs of the client by translating their needs into design requirements [17]. However, several integrated approaches for product design have been put forth in the literature to address the limitations of the conventional QFD in the context of developing a framework for sustainable product design because the conventional QFD places a limited amount of emphasis on customer requirements and its analytical approach lacks comprehensives and assumes certainty of decision-making. The Researchers already calculated the QFD by using QFD excel template. Fig. 8 shows the result of QFD to be considered in designing of innovative product.

The researchers identified six primary customer needs that were fulfilled using QFD: ease of weight, ease of use, multifunctionality, portability, ergonomic design, and affordability. To address these customer needs, the researchers established seven functional requirements for the product. These functional requirements encompass the use of plastic material, inclusion of an on/off button, provision of additional space for alcohol, independence from a power cord, ease of grip, affordability, and power efficiency. Among these requirements, the researchers aimed to maximize the functionality of 'easy to hold' while minimizing 'affordability.' The QFD, consisting of five functional requirements, aligns closely with the product targets. When the researchers mapped the relationship symbols between customer needs and functional requirements, it became evident that 'easy to use,' 'portable tool,' and 'ergonomic design' had strong correlations with the functional requirements. Conversely, 'easy weight' and 'affordable price' exhibited weaker correlations with the functional requirements. 'Multifunctional tool' demonstrated a moderate correlation. Additionally, in terms of customer importance ratings, 'easy to use,' 'easy weight,' and 'portable tool' were ranked 1st, 2nd, and 3rd, respectively. Each functional requirement was analyzed for its correlation, whether positive, negative, or neutral. The QFD analysis included four competitors, each with their unique strengths and weaknesses.

2.3. *Ergonomics aspects*

For anthropometry method, the Researchers collect the data from anthropometry data bank the criteria for this research are:

1. The age range starts from 7 years old until 50 years old.
2. Actively using laptop or computer on their daily life.
3. The genders for this research are male and female.
4. Indonesian people

The details of anthropometry data that were used in this study were listed in Table A2.

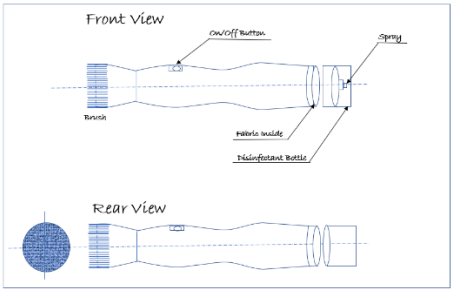

Figure 8. Fixed design of product

2.4. *Materials*

One of the supporting factors that are important to pay attention to in the success of a product design product material selection [18]. The use of improper materials has a negative impact that can thwart product design due to it affecting customer satisfaction. Often theoretical knowledge and practical experience data are combined to provide unique synergies and assist in the process of selecting raw materials. Some of the process of developing selection methods had been carried out by scientists [19].

Many factors need to be considered in the process of sorting raw materials. such as the position of the use of materials in the product to be made. When choosing materials for a particular application, a comprehensive approach is crucial. The first step is to identify the application's needs in terms of the qualities of chemicals, electricity, mechanical, and the environment. The second step is to use a process of elimination to choose the suitable material. The production method must also be considered because it is the most crucial. In designing this product, we decided to involve multiple criteria, direct rating method, systematic elimination method, and weight evaluation method as listed in Table A3 (see Appendices).

As per selection using tabular additive method, it is found that highest value is coming from Acrylonitrile butadiene styrene (ABS) Plastic with the value of 7.91 where other are below than that hence we decided to select ABS Plastic to use in this product. ABS material makes its main contribution to the price and commercial aspects. Different doping, surface finishing, and polymerization processes can be used with ABS material. Numerous qualities of the copolymer composed of acrylonitrile, butadiene, and styrene include low weight, ease of formability, resistance to abrasion [20]. In the manufacture of car components, sports equipment, and toys such as Lego blocks often rely on ABS as the material used [21] and listed in Table A4 (see Appendices).

3. Results and discussions

3.1. *Design product*

While the House of Quality is done. The researchers build some of free hand sketches for the non-measurement design. Initially, from the results of group discussion, the Researchers determined that there are

three alternative product designs which the Researchers will choose later by using the tabular additive method as listed in Table A5 (see Appendices). Based on Table A5, alternative C was selected and proceed with the design as shown in Fig. 8.

As it shown on the house of quality, there are some customer needs whose need to be fulfilled. The design is contained about 3 parts. The first one is the brush that can be unplugged from its main body part. The second part is the huge one. The design of this main part is adapted from the hand grip position. There is a power button the right side; this position will be easier to reach while the hand is on hand grip position. The main part will be connected to two different items such as brush and addiction disinfectant bottle. In the middle of main part and addition disinfectant bottle, there is a hole to keep the fabric or foam that advantageously as the cleaner support as shown in Fig. 9.

3.2. *3D Printing*

The researchers use 3D printing technology to build the prototyping [22]. Complex-shaped items that are challenging to make with standard manufacturing methods can be produced using 3D printing technology processes, which manufacture goods more cheaply and quickly, and its utilization and ubiquity in various industries are rising as a result of these benefits [23]. The process of converting a 3D image that comes from a regular digital file is also done using a 3D printing machine. This process is carried out by printing one by one from the layer of the product to become a whole product using the desired raw material. this process does not take a long time and the machine setup is complicated and large.

This makes the use of 3D printing machines loved by many people [24]. In the fields of agriculture, healthcare, the automotive, locomotive, and aviation sectors, mass customization and manufacture of any kind of open-source designs using 3D printing technology are becoming more common [25]. The use of 3D printing plays an important role in prototyping to mass production to get high quality [26].

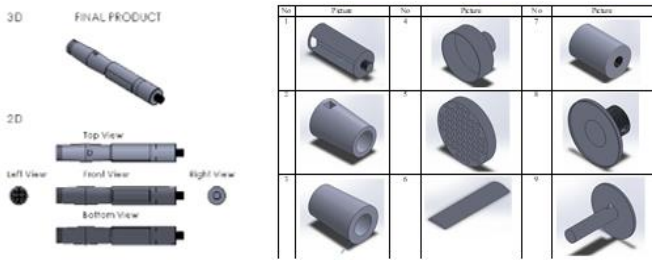

Figure 9. Final product and detail parts of prototype

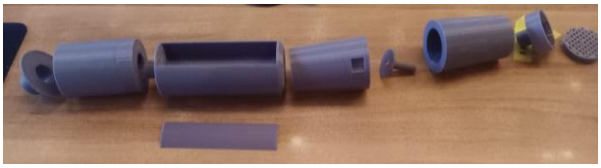

Figure 10. Detail part of prototype

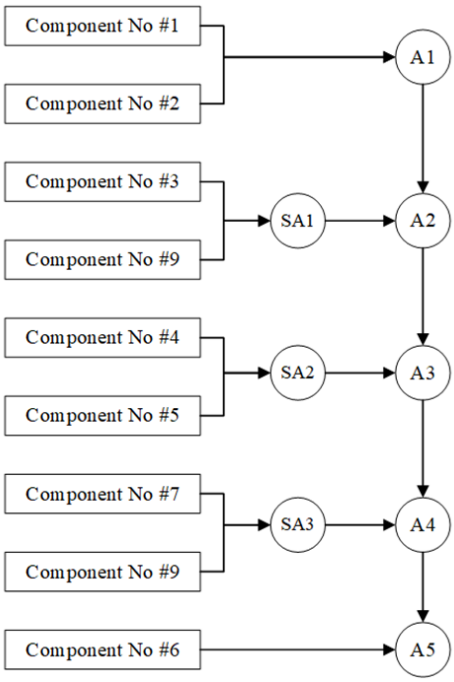

Figure 11. Assembly map for production

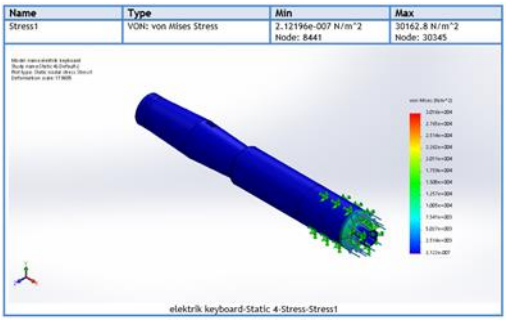

Figure 12. Stress analysis result

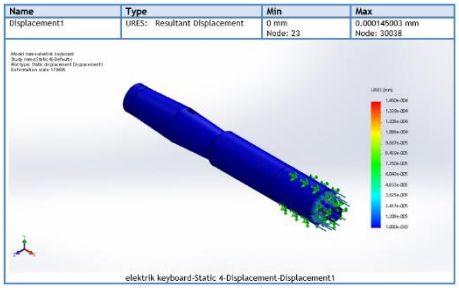

Figure 13. Displacement results

The SolidWorks software and 3D printing were used in this study to represents the selected design. SolidWorks software was used to design the Mold to generate a high-quality component while taking assembly and manufacturing efficiency into account [27]. For the prototyping, there are about nine different components that should be gather on one product. Those nine components are printed on the 3D printing, and it taken two working days to completed. The Fig. 10 shown the detail's components.

In total, the researcher has nine components. Those components need to be assembled. In the assembly step, before it becomes one product there are some processes that can be shown on the assembly map as shown in Fig. 11. As the result, the prototype can be used as its function very well. All the things like dust,

breadcrumbs, and anything else that often trapped on the keyboard are gone.

Fig. 12 shows the stress analysis. The conclusion of the stress simulation on the red part is the centre of the pressure on the object. The maximum pressure that occurs is achieved with the value of 30162.8 N/m2. While the whole part on its surfaces is defined by blue colour which means the product does have any stress pressure on its surfaces. The conclusion of the displacement simulation shown in Fig. 13 is maximum displacement 0.000145003 mm.

Fig. 14 shows the safety factor. The conclusion is safety because percentage of element with aspect ratio is more than 2 it means our product has low probability of failure, at the safety analysis we known if percentage of distorted elements is zero. So, we don't need to make any changes with our design product.

3.3. *Cost*

First, the Researchers must know about the detail direct material cost. Cost of direct materials contains about all the material used on the product. In this research, in terms of production one unit of Electrical Keyboard Cleaner, the Researchers need 0.25 kg ABS Plastic, 20 cm of Cable type 2x10, 1-unit electronic component, 1-unit brush, 1-unit push button/switch button, 1-unit fabric and 1-unit Motor DC. For the production Cost, it includes the Cost of direct materials, Cost of direct labor, and Overhead charges. In total, the production cost or the cost of goods sold will be Rp 55,900.00. After the Researchers analyze about the cost of goods sold and profit, the Researchers can define the selling price of the product. Initially, selling price will be the total number of cost of goods sold and profit. Therefore, based on the formulation, the Researchers got Rp 72,670.00 as their selling price. After determining some of the issues, the Researchers decide to make the selling price into Rp 75,000.00.

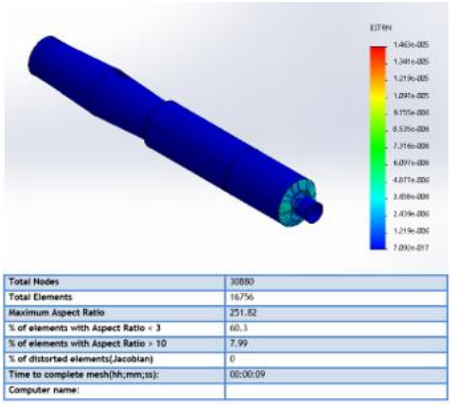

Figure 14. Factor of safety result

3.4. *Customer needs*

Based on the six customer needs, the research proved that light weight on the product to have a low weight by choosing ABS Plastic as the main material for the product. According to easy-to-use perspective, the use of the on/off button is expected by Researchers to meet customer needs in this easy to use.

Because users can start and end the keyboard cleaning process using just one key. Multifunctional tool tends to meet the needs of the third customer, Researchers added an additional function to the product in the form of alcohol space. Related to portable tool, the product is designed in the form of a small size so that it is easy to carry anywhere by the user. Ergonomic design on this research is supported by the size of the product allows the user to put the product in a laptop bag. In this case Researchers used some flattened sizes of the largest hand circumference of humans in general, small hand circumference and several other sizes. This is done with the aim that users can use the product easily and conveniently. Affordable price related to the previous cost calculation; it was known that this product can be sold at a price of Rp 75.000,00. This price is expected to be well received in the market.

Several factors have been considered during designing of the products, such as Anthropometric Dimension, Tabular Additive Method, Material and accessories, Material Criteria Calculation (Light weight, Easy to use, Multifunctional tool, etc.). The similar products which have been used before is only a manual cleaner for Laptop Keyboard, like a brush. If we compare with a manual cleaner, this product is more efficient since it has been designed with many considerations from Industrial design aspects.

4. Conclusions

Electric Keyboard Cleaner is a product designed to meet customer needs that have been identified through questionnaires. Several aspects have been considered by Researchers during process of product design up to prototyping. These aspects include Ergonomic aspects, materials, product durability, safety, costing, and others. The design has been achieved and implemented as per customer needs.

This tool is designed to clean computer keyboards from dust, other dirt between keyboard tuts, dirt on the surface of the tuts and prevent expensive repair costs. This research presents the development of a portable keyboard cleaner as an innovative alternative design. This research focuses on new ideas for product development and is expected to contribute to the development of products that are useful for people who spend their time working with Personal Computers or laptop.

The suggestion from this study is to minimize the number of components that may be possible in the future by changing the design process which previously consisted of several components that were connected until they became one turned into two components which are parts of the product. The challenge is how the Researchers designs the details in the product.

Declaration statement

Sri Wahyu Nensi: **Software, Conceptualization, Methodology,** Yunita Aulia: **Conceptualization, Data calculation, Writing - Original Draft**. Doly Mansyur: **Writing - Review & Editing, Resource, Formal analysis.** Taufik Roni Sahroni: **Data curation, Validation, Supervision.**

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Disclosure statement

The authors report there are no competing interests to declare.

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Data availability statement

The data that support the findings of this study are available from the corresponding author, [Sri Wahyu Nensi, Yunita Aulia, Doly Mansyur, Taufiq Roni Sahroni], upon reasonable request.

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Appendices

Table A1.
Reliability statistic

Cronbach's Alpha	*N* of Items
.610	6

Table A2.
Details of anthropometry data

No.	Body part	Dimensions	Data Calculation (cm)			Result (cm)
			Percentile	Size	Allowance	
1.	Hand Length	To determine the product's diameter	50th	17.05	1.5	18.05
2.	Hand Width	To determine the length of product	50th	9.43	1.5	10.93
3.	Thumb Length	To determine the right position of power button	50th	6.14	1.5	7.59
4.	Maximum Grip Diameter	To determine the product's diameter	5th	2.085	1.5	3.585
5.	Minimum Grip Diameter	To determine the product's diameter	95th	1.409	1.5	2.909

Table A3.
Tabular additive method

No	Criteria	Weight (W)	ABS Plastic		PVC Plastic		PBT Plastic		POM Plastic	
			Rating (R)	W X R	Rating (R)	W X R	Rating (R)	W X R	R	W X R
1	Environmentally friendly	0.14	8	1.143	8	1.143	8	1.143	8	1.143
2	Price or commercial	0.16	9	1.446	8	1.286	7	1.125	8	1.286
3	Safe material in terms of health	0.16	8	1.286	8	1.286	8	1.286	8	1.286
4	Good quality	0.14	8	1.143	8	1.143	8	1.143	8	1.143
5	Hard or strong	0.14	8	1.143	7	1.000	8	1.143	8	1.143
6	Scratch resistant	0.13	7	0.875	7	0.875	7	0.875	7	0.875
7	Easy 3D printing	0.125	7	0.875	7	0.875	7	0.875	7	0.875
		1.00		7.91		7.91		7.91		7.91

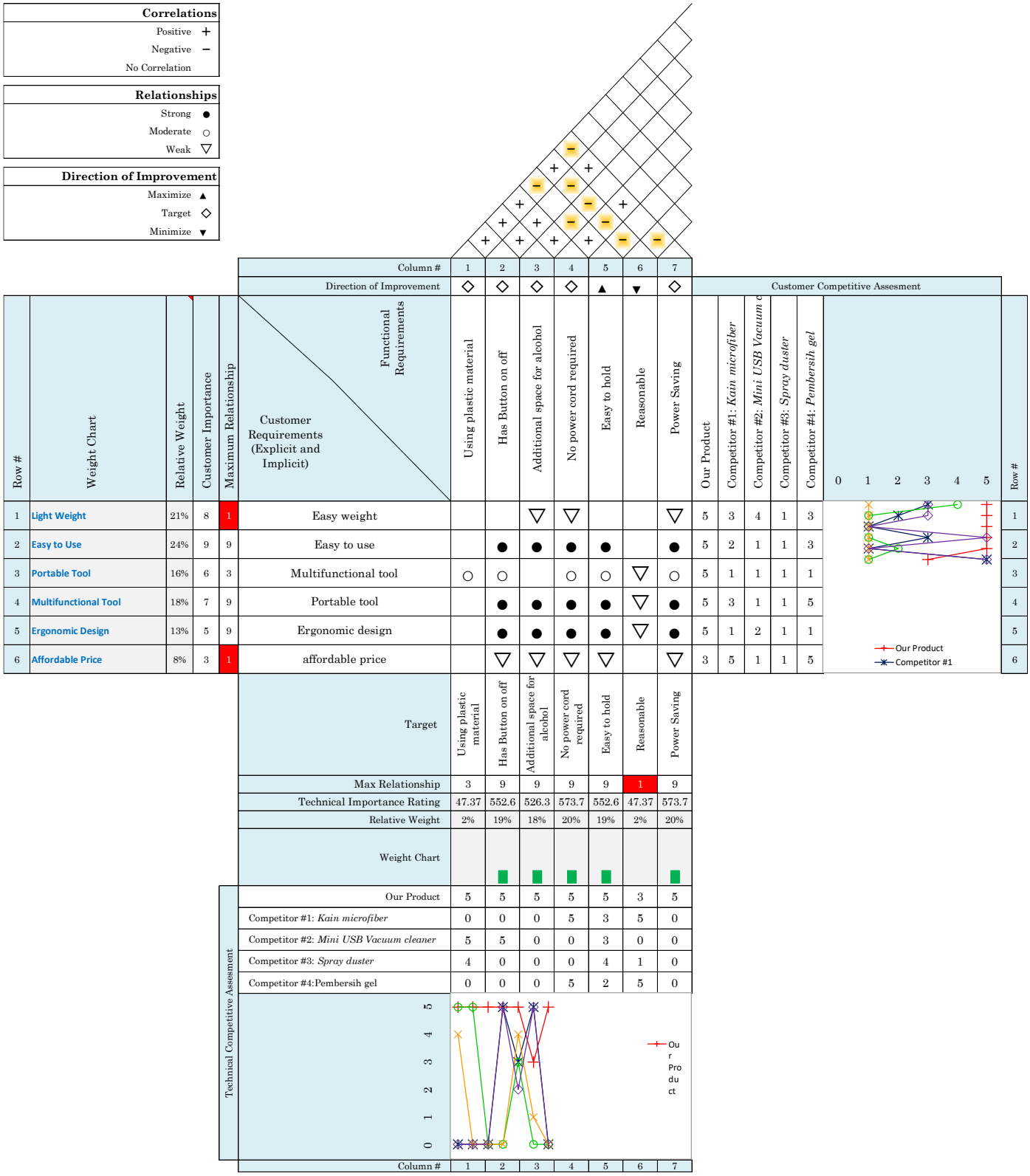

Figure A1. Result of House of Quality