

The Conceptual Framework of Quality Product Design Based on Computer Aided Design (CAD)

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Abstract

Producing a sustainable product quality and innovation ecosystem is not an easy thing, especially in the product development stage. Therefore, Computer-Aided Design (CAD) software can be utilized as an important tool to develop the creative design and quality product. This paper discussed the conception of quality design for the production of product design. This study employed systematic review of producing a conceptual framework to examine the systematic development process of product design quality with the product design requirements, design product concepts, detailed product design and product design evaluation of the aspects of quality products. The result of the conceptual framework developed shows that the initial stage of idea-generating is an essential element in the design, supporting a systematic process that can produce innovative, creative and quality product design.

Keywords

Product Design Requirement, Design Product Concept, Details Product Design, Design Quality Aspect

1. Introduction

The production of a product should expand into global markets for Industries Revolution 4.0 (IR 4.0) is increasing rapidly nowadays. A systematic and well-planned design process in manufacturing must meet the standards according to industries demand (Sulaiman, Shapi, Hasan, & Prabuwo, 2011; Tayal, 2013) especially in the era of IR 4.0. The manufacturing cost of a product can be reduced by producing a quality product (Bon, 2010). Also, making adjustments to increase productivity by industries today needs to consider the minimum-maximum cost of production, choosing the optimal design in specific tasks and responds to the new product design (Schey, 2009). Meanwhile, users'

interest in product design is one of the important elements to produce a high-quality product (Ulrich, 2011). Feedback from user and product design problems is a significant activity to implement the improvement of a quality product in manufacturing industries (Page, 2014). Therefore, the innovation and creativity of the designer must be highlighted to generate a product according to users' desire; the requirement of effective product design should represent users' opinions (Backhaus, Jasper, Westhoff, Gausemeier, Grafe, & Stöcklein, 2014). Hence, innovation element plays an essential role in activating constructive and creative ideas in the production of quality products.

To create a sustainable innovation ecosystem is not an easy thing, especially in the product development stage. The students' weaknesses in mastering the aesthetics, ergonomics, and brainstorming led to lower quality and value in the production of the product design. A study conducted by Hassan, Ismail, & Mustapha (2016) to the students of the Polytechnic in Malaysia demonstrates that there are significant differences in forwarding the initial ideas of product design produced in the synthesis activity using integration technology such CAD software ($M = 80.6$) compared with synthesis using conventional methods ($M = 67.1$), $t(1.18) = 17:18$. This result proves that initial ideas of creativity and innovation design can be generated from the integration of technology better than the conventional method.

Considering the above factors, the standards required to produce quality design cannot be met if there is no specific strategy implemented comprehensively. Furthermore, government's annual spending on R&D is high and increases with statistics showing the allocation from 2010 of RM8.51 billion to RM10.61 billion in 2012 (MASTIC, 2013) to be used to select companies and universities around the country. The government is also taking steps to promote innovation activities in product design, not only in the industry but also in educational institutions. Unfortunately, it is a waste to the country as the high provision to produce thinkers, designers, and production of products can provide an excellent return to the national economy but is not efficiently optimized. The purpose of this systematic review is to establish the concept of product design to produce a quality design. The combination of theories, models, and findings from scientific articles will adopt in the formation of a complete conceptual framework underlying the study.

2. Methodology

The systematic reviews were used to generate a conceptual framework for developing a model to produce product quality in the student learning context. Systematic reviews are designed to detect, assess and synthesize best research-related problems by providing research and findings to the issues being studied (Boland, Cherry, & Dickson, 2013). According to Gough, Oliver, and Thomas (Gough, Oliver, & Thomas, 2012), a systematic review is a method to form a theory, create evidence and solve a research problem. Merriam (2002) also explained that by collecting and analyzing information generated by reading

a document from multiple sources, research could carry out thoroughly. The same method has also been used by [Ashari, Rasul, & Azman \(2014\)](#) in identifying the individuals, the environment, and adaptability to the selection of students career of skills certificate system in Malaysia.

Related information obtained from various government agencies, reports, articles, books, newspapers and electronic reference through a similar website. The databases and journal articles that were referred to are ProQuest, EMERALD, Science Direct, MyCite, and MyDoar. Keywords for searching information is the product design requirement, product design concept, detailed product design, product design evaluation, product design quality, product design based on CAD and innovation in product design. Further analysis was conduct to identify the elements for each construct of product design. The construct of the quality product design is product design requirement, the product design concept, detailed product design, product design evaluation. Meanwhile, the quality product design elements consist of research on information, design specifications, production design concept, design concept sketch, evaluation and selection of design concept, three-dimensional modeling (3D), detailed design drawing, evaluating students' understanding and scientific design idea's.

Based on the list of reference items for this systematic review, information searching leading to studies by the previous researcher. Thus the researcher lists some articles to aid in explaining in detail the design requirements for the production of quality products as shown in [Table 1](#).

3. Discussion

[Ekuan & Stewart \(2000\)](#) define design as a process for realizing the ideas in the products form. The resulting product has aesthetic characteristics, functions and capable of solving user problems. This design defined as the process of transforming ideas into products that can be used to end user ([Koskinen, Zimmerman, Binder, Redstrom, & Wensveen, 2013](#)) using scientific principles, technical information, and imagination to realize quality product design ([Jalil, 2000](#)). Produce high quality and innovative products depending on the designer's ([Choo, Weng, & Ghazali, 2011](#)) in line with creative and critical ideas. The process of designing creative ideas with the application of problem-solving methods is the most critical process as the resulting product must meet the specifications according to the user's request ([Mao, Luo, Li, Luo, & Wang, 2011](#); [Sulaiman, Shapi, Hasan, & Prabuwno, 2011](#)). Problem-solving is also emphasized by [World Design Organization \(2017\)](#) in the planning process to promote innovation and lead to better quality of life through products, systems, and services. The organization also sees the problem as an opportunity to link innovation ([Industrial Designers Society of America, 2017](#)), technology, research, economics, social and environmental in developing product design. Problem-solving and creative thinking are needed to provide ideas in the process of improving quality product design and meeting established standards ([Choo, Weng, & Ghazali, 2011](#); [Ullman, 2010](#)).

Table 1. Part of list related research for systematic review for the quality product design conceptual framework (QPDCF).

Researchers	Research Design	Related to QPDCF
Mao et al. (2011)	Research on the development of product design using simulation to produce thermal engineering design for apparel products in the image 1D, 2D, and 3D with multifunction CAD system.	Detailed Design Product
Choo et al. (2011)	Case study systematically brainstormed to the mobile table for laptop product type	Product Design Requirement
Sulaiman et al. (2011)	Experimental study 'Rapid Application Development (RAD). RAD life cycle consists of four phases: planning, analysis, design, and implementation of the effectiveness of CAD in designing hip joint implant.	Product Design Concept
Chandrasegaran et al. (2013)	Literature Review and development to study the evolution of research in product design from the past to the current trends and make predictions of future development. (Chandrasegaran, Ramani, Sriram, Horváth, Bernard, Harik, & Gao, 2013).	Product Design Requirement, Product design evaluation
Soni et al. (2013)	Research on design development using a fuzzy method. The research was conducted to develop support systems based on knowledge on aesthetic design for an industrial product. Aesthetic characteristics studied were "cute," "strong," "slender" and "elegant.	Design Quality Aspect product design evaluation
Tayal (2013)	Literature/systematic review to develop a product design by identifying the key elements in the design process, such as setting objectives and criteria, synthesis, analysis, development, testing, and evaluation.	Product Design Requirement Product Design Concept Detailed Design Product Product Design Evaluation
Xenakis & Arnellos (2013)	Content analysis research to form theoretical concepts related to aesthetics and interaction with the product design process.	Product Design Concept Design Quality Aspect
Deng et al. (2014)	Qualitative and quantitative analysis of color images on product design (Deng, Yu, Wang, Chen, & Liu, 2014)	Design Quality Aspect
Olabanji & Mpofu (2014)	Assessment of analysis using matrix method identifying the conceptual design approach Computer-Aided Design (CAD) based on the requirements of usability, cost, and manufacturing capabilities.	Detailed Design Product product design evaluation
Osakue (2015)	Experimental study on the feasibility of rubric criteria for the evaluation of training quality 3D CAD modeling in designing quality new products.	Product Design Concept
Ismail (2015)	Study on design development to develop and test a Mobile-based performance (MobiCAD) prototype in the course of Computer-Aided Design (CAD) to improve the problem-solving skills of students in polytechnics (Ismail, 2015).	Product Design Requirement

3.1. Model and Product Design Process

The models related to the product design process by Alli & Rahman, Jalil, Ulrich & Ep-pinger, Design Council UK and British Standard Institution. However, this

study uses the models developed by Ulrich & Eppinger and Jalil as the primary framework in construct the conceptual framework, and other models described above applied to strengthen the main model (Ulrich & Eppinger, 2012; Jalil, 2000). The process begins with the need to plan, analyze, and define design problems and studies on design specifications, conceptual design, production, evaluation and concept selection, detailed design, design optimization, detailed drawings production and list of materials, prototype construction, test and final product performance improvement (Ulrich & Eppinger, 2012; Jalil, 2000).

3.2. Construction of Conceptual Framework

Based on the model presented by Ulrich & Eppinger and Jalil, a constructed conceptual framework is shown in **Figure 1**. Within this conceptual framework, researchers are integrating ten design process that makes four significant design process, namely: 1) Product Design Requirements; 2) Product Design Concepts; 3) Detailed Design Products, and 4) Product Design Evaluation. The four major product design processes are positioned as the entire process for the model of product design that will be developed and studied. The manufacturing process, the construction of the prototype and the final product is removed from the framework by taking into account that this study did not involve the production of prototypes and actual products. On the other hand, the quality of design that contains aspects of aesthetics, ergonomics, color, usability included in this study is as guidance for the production of quality products. The aspects of the product design process in the industry by Ulrich & Eppinger and research on the methods of product design from previous studies (Ibrahim, 2013; Alli & Rahman, 2008) are well-known in the study of quality product design. The researchers identified one component and two aspects in product design requirements, the two components and the three aspects of the design concept, one component and two aspects of the detailed design of the product and one component and two aspects in the evaluation of product design.

3.2.1. Product Design Requirement

The component for product design is the design orientation (Needham & Hill, 1987) to provide a preliminary view of the product to increase the student's interest in the product to be created. The first aspect identified for design needs is the analysis and design definitions with the problems faced by consumers, and this has recognized through in-depth research conducted by the designer. After issues meet by the user are identified, the second aspect is the study of the product design survey information related to the preliminary survey of the product (Taib & Hanafiah, 2006) to resolve the problems (Jalil, 2000). The product planning process also involves creative brainstorming ideas and problem-solving methods (Ilevbare, Probert, & Phaal, 2013; Jin & Li, 2009) by obtaining information from multiple sources. Besides that, exploration and comparison the design analysis is also part of the need to design products (Tayal, 2013).

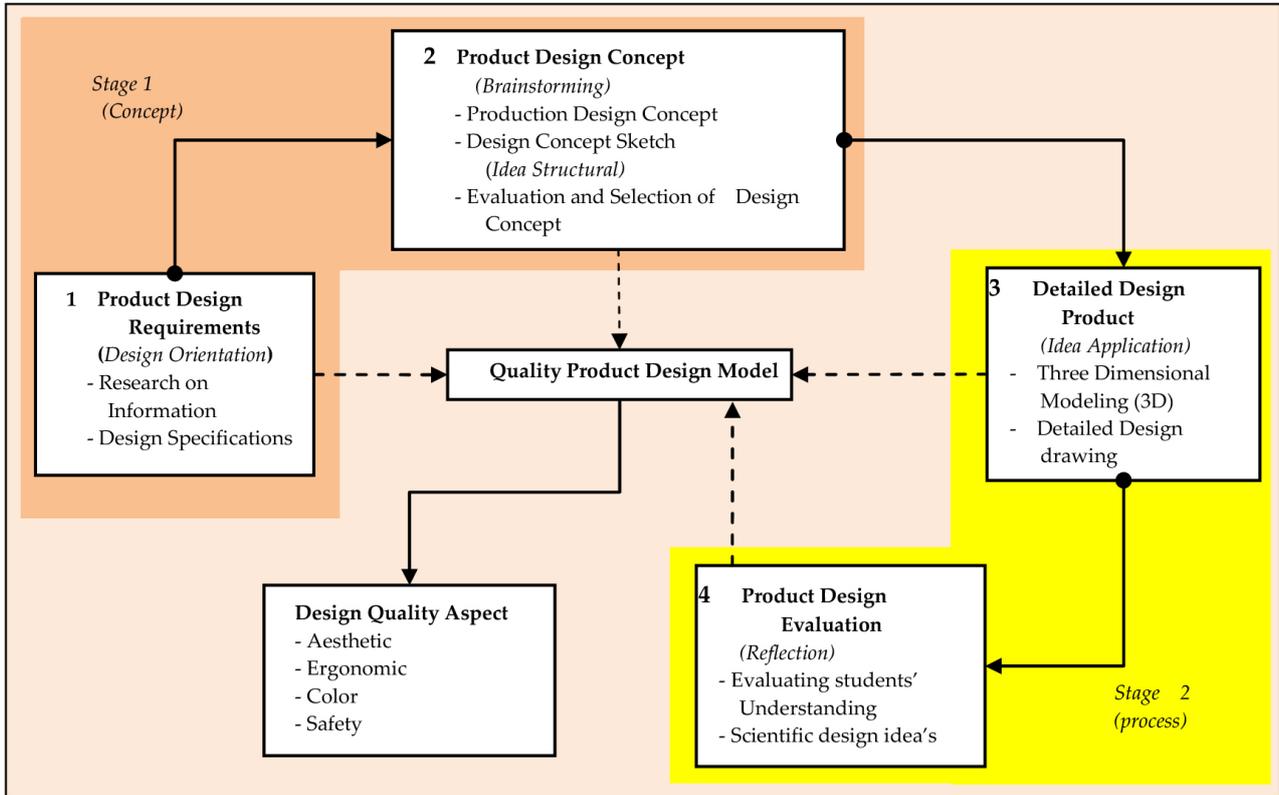


Figure 1. Quality product design conceptual framework (QPDCF).

3.2.2. Product Design Concept

The component design consists of brainstorming and basic ideas (Needham & Hill, 1987) to increase awareness of the importance of the user experience with product design (Bruckman & Resnick, 1995) and the existing student ideas in product design to raise awareness of new knowledge by transforming, adding and replacing existing ideas with scientific value (Resnick & Ocko, 1991). These ideas are brain-stormed in the minds of students in the form of a visual abstract. The importance of brainstorming and structuring ideas for product design concepts could be triggered by brainstorming through critical thinking and systematic processes (Sulaiman, Shapi, Hasan, & Prabuwo, 2011). Based on the ideas identified, the next step is to draw on concepts in the design process by combining visual thinking and creativity (Hussain, 2004). These ideas and sketches form the plan to be judged by the method of valuation matrix based on the evaluation table, developed by Professor Stuart Pugh, known as Pugh's Concept Selection (Jalil, 2000; Ulrich & Eppinger, 2012) to get the final design concept that meets the specifications. Therefore, based on the Assessment Table with the matrix, the selection of the final design concept will be translated into drawing by making improvements if necessary (Olabanji & Mpofu, 2014; Ulrich & Eppinger, 2012).

3.2.3. Details Design Product

The component for detailed product design is an idea-generating (Needham &

Hill, 1987), which emphasizes the strengthening of new abstract ideas about product designs built into the minds of students for applied in the form of graphic that is product drawing. The first aspect is the three-dimensional (3D) CAD modeling drawings (Batchelor & Wiebe, 1995; Bilalis, 2000; Osakue, 2015), which emphasizes on the production of design models such as features, sizes, colors, surface finishes and significant product dimensions (Baddam, 2014; Ulrich & Eppinger, 2012). The second aspect is the detailed drawing of the product design that is produced to show the detailed of the component. The completion of the component can illustrate essential product features such as 1) painted on a scale (Hassan, Ismail, & Mustapha 2016; Osakue, 2015); 2) the critical dimensions of the product (Company, Contero, Otey, & Plumed, 2015); 3) standard drawing format as in BS308 Engineering Drawing Practice or ANSI AS Standard Y14.5M. Dimensions and tolerances (Quintana, Rivest, Pellerin, Venne, & Kheddouci, 2010); 4). each component labeled with a list of reference materials and v) a list of the design product material listed in the drawing (Resnick & Ocko, 1991). The use of CAD software for applications detailed designs can assist students in creating designs, especially showing 3D images of products (Sheil, Migayrou, Pearson, & Allen (Eds.), 2016; Tang, Zhou, Wang, Liao, & Tao, 2014).

3.2.4. Product Design Evaluation

Product design evaluation contains aspects of reflection (Needham & Hill, 1987) that allow students to be aware of the changes in the existing ideas and their scientific values (Papert & Harel, 1991). This scientific value can help students with critical reviews and arguments in highlighting ideas about product design. The first step in the product design evaluation process is to evaluate student understanding of product design production. Product designed by students in the form of detailed drawings produced by CAD (Taib & Hanafiah, 2006; Ulrich & Eppinger, 2012) which assessed design quality aspects such as aesthetics, ergonomics, colors, usability, and safety (Chen & Wang, 2012; Pheasant & Haslegrave, 2016; Sethi, 2000; Mohd, 2012). The second step is a scientific idea that emphasizes the process of shifting the existing abstract concept into a 3-dimensional CAD drawing containing scientific elements that require systematic CAD commands (Vaský, Eliáš, Bezák, Červeňanská, & Izakovič, 2010). By the theory of constructivism, together with the existing experience, form a mental model of the students actively designing the product and thereby build their knowledge. The mental model is then used to receive new skills (Robertson & Radcliffe, 2009; Speed, 1991).

3.3. Design Quality Aspect

The product design quality aspect based on CAD has identified. The product quality aspect of the product is aesthetics (Sethi, 2000), ergonomics (Pheasant & Haslegrave, 2016; Mohd, 2012), product colors, product usability, and product safety (Chen & Wang, 2012; Alli & Rahman, 2008; Ibrahim, 2013). The quality

aspect used as a guide to quality-designed products through the design process has mentioned above.

3.3.1. Aesthetics of Product Design

Dieter and Schmidt (Dieter & Schmidt, 2013) state that aesthetics are how the product appearance, feels, sounds and smells. The customer's response to this dimension is the subject of personal judgment and individual priorities (Gharakhani & Eslami, 2012). The aesthetic assessment of a product is highly subjective. Everyone is different and has views and insights and may differ from their opinions, interests, and ideas in producing the product (Lee & Koubek, 2010). However, this condition does not affect the product. The interpretation given with aesthetics refers to the characteristics and characteristics of the product such as beauty, warmth, tenderness, and harmony of product function (Institut Pendidikan Guru Malaysia, 2015). Aesthetics are the extent to which the design of the product attracts users to have products (Lee & Koubek, 2010; Sethi, 2000; Xenakis & Arnellos, 2013). Critical issues affecting aesthetics are ergonomics, i.e., planning work to fit employees, rather than forcing employees to provide their position (US Department of Labor, 2000), and the design meets the user's convenience.

3.3.2. Ergonomic of Product Design

Ergonomic concepts have existed since 1700. Today, ergonomics play an essential role in improving the product design process (Mohd, 2012). Ergonomics is a broad field and includes various disciplines such as psychology, physiology, biomechanics, and anthropometrics. However, ergonomics mostly refers to the satisfaction and interaction between the product and the user with the scientific study of the physical, product-capable and product-user criteria. Ergonomics are also crucial in designs that are strictly related to physical products and systems (Kroemer, Kroemer, & Kroemer-Elbert, 2001). In the field of industrial design, ergonomics played an essential role in product development and associated with the study of users in working environments (Bridger, 2008; Das & Mishra, 2015; Norris & Wilson, 1997). Ergonomic technically emphasis on consumer comfort while using consumer products such as physical posture, product use and environmental safety (Sagot, Gouin, & Gomes, 2003). For example, office chair design must take notice of physical posture so that the user does not feel ill, especially behind. Ergonomics are also closely related to the user-friendly, especially those relating to comfort or handling during use.

3.3.3. The Color of Product Design

Color has a function in the beauty and value of the product (Bloch, 2011). Color can affect the market for the product and is a fundamental matter in the product design process (Shi, 2013). The purpose of the color application is to create an atmosphere or mood for the user. Also, the color of the product will explain the function of the product (Ibrahim, 2013), and from the drink to the consumer electronics, the marketer uses the colors in an innovative way (Ilevbare, Probert,

& Phaal, 2013). For example, the top three-color response to be seen in products and branding related to words that are natural products and green gardening (nature) and television mostly black, or silver (technology) (Page, Thorsteinsson, & Ha, 2012). In addition to visual effects, colors give different stimuli to individual mental and physical perceptions (Ou, Luo, Woodcock, & Wright, 2004). Visual preferences for particular colors should be given priority not to affect product designs that may affect product marketing and customer willingness to buy (Kauppinen-Räsänen & Luomala, 2010). During the design process, the use of 3D CAD can automatically choose the product's color design and can finalize the proposed design color more efficiently on any product (Baddam, 2014; Tsai, Hung, & Hung, 2007). The time required to produce color schemes by CAD is satisfactory and the use of a shorter time compared to the traditional process (Chen & Wang, 2012).

3.3.4. Safety of Product Design

The safety factor for consumer products is an element that must be prioritized to ensure that it continues to gain attention and market demand. Security is also an important thing during the initial design process. According to the General Product Safety Regulations (GPSR) (Viscusi & Cavallo, 1994) and the Provision and Use of the Work Tool Regulations 1992 (Britain, 1997; Stranks, 1994), manufacturers or manufacturers are required to ensure that all products are released on a minimum phase of an accident and probable injury. Product safety is divided into two parts: 1) protection against structural form, which is a reference to the material used, production quality and product components; and 2) design safety means the concept presented will have high durability and will not cause injury or abuse (Ullman, 2010). According to Sagot, Gouin, & Gomes (2003), safety products include the safety of construction products that involve the use of materials, components and production quality (Bloch, 2011). The need for detailed design also plays an important role in the design of security products, because when there is a change to the product design, improvements will be made to design details (Leveson, 2011). Therefore, before the product is designed and marketed, manufacturers are responsible for the safety tests prescribed by the standard.

Figure 1 shows the construct and the elements of quality product design based on all the explanations above. Four constructs are product design requirement, the product design concept, detailed product design, product design evaluation. Meanwhile, the quality product design elements consist of research on information, design specifications, production design concept, design concept sketch, evaluation and selection of design concept, three-dimensional modeling (3D), detailed design drawing, evaluating students' understanding and scientific design idea's. All construct and elements selected based on the current requirement and issues that appeared in the process of quality product design. The conceptual framework was used to developing a model to produce product quality in the student learning context.

4. Conclusion

Design requirements and design concepts are viewed importance in realizing the development of quality products at the beginning with the triggering idea related to the production of quality product design. At the brainstorming level, the triggering of ideas occurs through a systematic method that can generate innovation and creative problem-solving. The detailed product design level can promote design concept to a product design model in graphical form by using the CAD application. It can assist in product design, starting from the concept stage through to documentation (detailed design drawings). Further research can help provide empirical evidence of the importance of components and aspects of the design process, such as product design requirements, the concept of product design, product design details and product design evaluation to produce a model of quality products.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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