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A Content Analysis on Quality for CAD Based Product Design: Developing a Framework for Malaysian Technical Teacher Training Institute

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Abstract: Product design is a complicated process and requires a systematic requirement and specification to produce sufficient quality to remain competitive. One of the most important components in the design process is Computer-Aided Design (CAD), which renders a detailed drawing in either two-dimensional (2D) or three-dimensional modeling (3D). This paper discusses the conception of quality design to produce a creative design product. This study employed a systematic review to produce a framework of quality product design based on Computer-Aided Design (CAD). Out of 210 papers that were identified, 102 were reviewed and also 12 other relevant articles, books, reports, and documents, hence a total of 114 papers were included in this review. The reviews revealed that there are main aspect drivers of the product design, design process, design quality, customer need on the product, product evaluation, and design concept of quality products. The study also showed that the initial stage of idea-generating is an essential phase to produce innovative, creative and quality product design. This framework is useful as a guide for teachers to standardize product design concept and to assist Malaysian design and technology trainee teachers in producing a quality product design. Finally, this research proposes a conceptual framework based on our propositions. The proposed quality product design framework is beneficial to be used as a guideline for the Malaysian Technical Teacher Training Institute and policy makers to enhance the skills in the development of a quality product.

Keywords: Product design framework, quality of product, design product concept, Computer-Aided Design

1. Introduction

The development of manufacturing technology products is increasing rapidly nowadays; therefore, the production process should not be limited to the domestic market but expanded into global markets. The production process must pass a systematic and well-planned process so that each manufactured product meets the set criteria and standards (Sulaiman et al. 2011; Tayal, 2013). Currently, to produce quality product design, a teacher trainee must learn high-level technology in their field as well as Computer-Aided Design (CAD). In an engineering context, CAD is widely used to design and develop products to be used by customers. CAD drawings offer the flexibility to draft and design in a digital sphere, which was previously done by hand. Many CAD programs are now using three-dimensional (3D) drawings to maximize productivity and provide quicker and better product results allowing for the development of the details. Using CAD programs in the manufacturing industry today should be capable of making adjustments to increase productivity by considering the minimum-maximum cost of production, responding to changes and rapid manufacturing, cost control and choosing the optimal design to solve specific tasks (Schey, 2009).

Development of product design is increasingly viewed as essential to attract users to own every designed product (Harston, 2012). Generations of good income by individuals, companies and industries are obtained by maintaining consumer loyalty to the design family (Shaukat, 2012). Attractive design and quality depend on the product characteristics (the aesthetic value, ergonomics, colour, overall shape, function, safety, etc.) and these factors influence

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the consumers to get the product (Kroemer, Kroemer & Kroemer-Elbert, 2001; Ma, Chen & Wu, 2007; Soni, Khanna & Tandon, 2013).

In the Malaysian context, the production of creative and quality products still requires effort. A competitive global economy with rapid development shows that the focus is on the development of human capital with knowledge and skills in product design (Institut Pendidikan Guru Malaysia, 2015), while quality should be a priority (EPU, 2015; MITI, 2015). Knowledge and skills are part of a human capital development that needs to be nurtured and developed for the future of our country (Bahagian Pendidikan Guru, 2009; Malaysian Qualifications Agency, 2014).

The Organisation for Economic Co-operation and Development (OECD) reviews by Innovation Policy in Southeast Asia 2013 reported that on average, only 5.5% companies in Malaysia are actively involved in R&D and there is a lack of critical thinking skills among students from the lower level to a higher education institution level, with the achievement of 52nd out of 65 countries participating in the Program for International Student Assessment (PISA) with an average score which is below the global average score. These factors are caused by the lack of "soft skills" in most students, such as critical thinking, communication and innovation (EPU, 2015).

To create a sustainable innovation ecosystem is not an easy thing, especially in the product development stage. To figure out whether the matter above affects the construction of creative ideas to produce quality product design, several reports and studies from previous researchers showed the importance of creative ideas and highlighted that new ideas in design are supported by the integration of technologies such as Computer-Aided Design (CAD). Data from the analysis of the course work for students studying Design and Technology in CAD show that 65% of students do not master the aesthetic elements such as characteristic appearance of the product, end packaging of the product, or the function of the product; 55% of students do not master the elements of ergonomics that include the comfort features to the user and functionality of the product; while 60% of students are uncertain in the initial ideas brainstormed, such as finding information about a product to be designed and translating the product characteristics into sketches (aesthetic and ergonomic elements) in product design innovation (Unit Penilaian dan Pentaksiran IPGKPT, 2016).

Considering the above factors, the standards required to produce quality design and meet global standards cannot be met if there is no specific strategy implemented comprehensively. Also, there is still a lack of framework in product quality based on CAD, especially in the Malaysian Technical Teacher Trainees Institute. The purpose of this content analysis is to produce a framework of quality product design based on CAD. The reviews revealed that there are main aspect drivers of the product design, design process, design quality, customer need on the product, product evaluation, and design concept of quality products. This framework is useful as a guide for teachers to standardize product design concept and to assist Malaysian design and technology trainee teachers in producing a quality product design. Finally, this research proposes a conceptual framework based on our propositions.

2. Methodology

The method of document analysis and systematic reviews were used to generate a conceptual framework to develop a model of quality product design based on CAD in teacher trainee 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 (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 analysing information generated by reading a document from multiple sources, research could be carried out thoroughly.

2.1 Material Collection

Research papers published between 1987 to the present were included in this systematic review. Related information were obtained from various government agencies, reports, journals, books and electronic references through a related website. The keywords for searching information are product design, design process, design quality, product design based on CAD, computer-aided design, and innovation product design. Recently published systematic reviews of closely related topics were considered as guidelines for this research (Chiu & Chu, 2012; Ilevbare, Probert & Phaal, 2013; Krishnan & Ulrich, 2001; Xavier et al., 2017). The articles listed from the initial search were refined with the help of a series of steps, as depicted in Figure 1 (Paras, Pal & Ekwall, 2017).

2.2 Practical screening based on the keywords

Systematic screening criteria were defined. Only peer-reviewed articles, books and conference papers written in the English and Malay language were considered for the review. Screening was performed in two stages with different sets of primary and secondary keywords. In the first stage, 'product design', 'design process', 'design quality', 'customer need on product', 'product evaluation' and 'design concept' were the primary keywords with a set of secondary keywords ('product design based on computer-aided design (CAD)', 'innovation product', 'aesthetic', 'ergonomic', 'colour' and 'sketching'). At this stage, 142 articles were selected to understand the current practice of concept of quality product design. In the second stage, articles were searched with the help of primary keywords and 'CAD', 'innovation product', 'aesthetic', 'ergonomic', 'colour' and 'sketching' as secondary keywords. Overall, 210 articles

were found at this stage from the perspective of quality product design in technical and vocational education training (TVET) in Malaysian institutes. The databases and journals used were ProQuest, EMERALD, ScienceDirect, MyCite, Scopus, and ISI Web of Science (WoS).

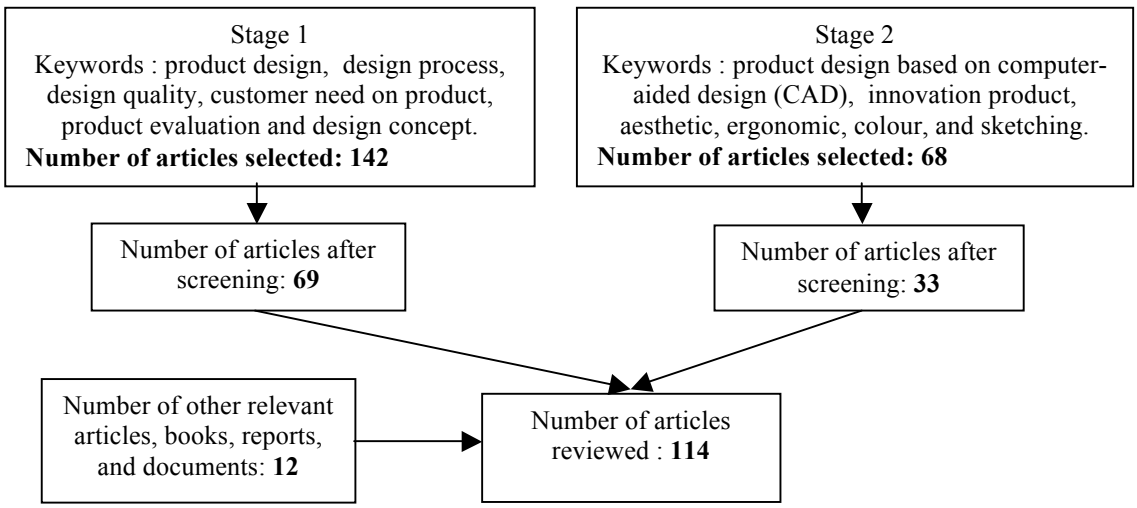

Fig. 1 - Selection of articles

2.3 Screening Process

All articles were downloaded and transferred to a reference-management software. Articles were initially screened by reading the title, abstract and conclusion. Articles related to 'product design', 'design process', 'design quality', 'customer need on product', 'product evaluation' and 'design concept' were selected. Relevant articles from other areas with a significant discussion on the designing product were shortlisted. On this basis, 65 articles on product design and design process, along with 27 articles on product design based on CAD and innovation product were retained. Detail about the articles selected at each step is provided in Table 1.

Table 1 – Keywords used for article selected.

Stages	Keywords	Total number of articles	Total number of screened articles
1 (Primary keywords)	'product design', 'design process', 'design quality', 'customer need on product', 'product evaluation', and 'design concept'	142	69
2 (Secondary keywords)	'product design based on computer-aided design (CAD)', 'innovation product', 'aesthetic', 'ergonomic', 'colour', and 'sketching'.	68	33
Others	Relevant articles, books, reports, and documents	12	12
	Total	222	114

2.4 Descriptive analysis

The distribution of articles has been analysed over a specific period. The selected articles were published from 1987 to 2017; the number of articles published in this time span is depicted in Table 2. The number of articles published has increased in recent years. The primary reason for the increase is the growing consumer need for quality product design caused by the frequency of product design specification by the industries. Industries have become more conscious and are making adjustments to increase productivity by considering the cost of producing new products. Table 2 also shows the analysis of research articles based on their focus area, i.e. product design requirement, product design concept, detailed product design, and product design assessment, which constituted 60.5%. Research related to product design based on CAD, innovative product, and design quality (28.9%) are still in the nascent stage. Many studies have been focused on product design (Page, 2014) and design process (Singhry, Abd Rahman, & Imm, 2016).

Table 2: Keywords used for the article selected by years

Design Aspect	< 1994	1995 - 1999	2000 - 2004	2005 - 2009	2010 - 2014	2015 - 2017	Total
Product design requirement, product design concept, detailed product design, and product design assessment.	3 (2.6%)	2 (1.8%)	6 (5.3%)	6 (5.3%)	40 (35.1%)	12 (10.5%)	69 (60.5%)
Product design based on computer-aided design (CAD), innovation product, and design quality.	4 (3.5%)	2 (1.8%)	1 (0.9%)	6 (5.3%)	13 (11.4%)	7 (6.1%)	33 (28.9%)
Other relevant articles, books, reports, and documents.	0 (0.0%)	0 (0.0%)	1 (0.9%)	2 (1.8%)	5 (4.4%)	4 (3.5%)	12 (10.5%)
Total	7 (6.1%)	4 (3.5%)	8 (7.0%)	14 (12.3%)	58 (50.9%)	23 (20.2%)	114 (100.0%)

This studied systematic reviews were also analysed based on publication across the Scopus Q1 journal rankings. This information is shown in Table 3. Most of the papers were published in Design Studies (11), Journal of Engineering Design (07), Applied Ergonomics (05), Journal of Product Innovation Management (05), CIRP Annals - Manufacturing Technology (05), Journal of Mechanical Design (04), Journal of Marketing (04), Research in engineering design (03), Journal of Cleaner Production (03), Educational Technology Research and Development (03), International Journal of Technology and Design Education (02), International Journal of Design (02), and European Journal of Engineering Education (04). These articles focused on product design, design process and design quality. In contrast, the articles published in Computer-Aided Design (06), Computers in Industry (04), CAD Computer-Aided Design (04), and Computers & Industrial Engineering (03) focused on product design based on CAD. Overall, the selected articles were published in the Scopus Q1 journal rankings (refer to Appendix A), indicating that this research topic has numerous dimensions that can enrich knowledge by providing multiple perspectives.

Table 3: Top Journal by number of Scopus Q1 rankings publications

Journal	Number
Design Studies	11
Journal of Engineering Design	7
Computer-Aided Design	6
Applied Ergonomics	5
CIRP Annals - Manufacturing Technology	5
Journal of Product Innovation Management	5
CAD Computer-Aided Design	4
Computers in Industry	4
European Journal of Engineering Education	4
Journal of Marketing	4
Journal of Mechanical Design	4
Computers & Industrial Engineering	3
Educational Technology Research and Development	3
Journal of Cleaner Production	3

The author's affiliation with a particular country or region can provide a clear perspective of the research and development trends in the region. Table 4 shows that most of the studies on product design requirement and product design concept were conducted in the United Kingdom (UK) (21.1%), and the majority of studies on product design based on CAD and product innovation (11.4%) were also conducted in the UK. Other countries indicated that in recent years, there had been an increasing (18.4%) number of studies related to product design requirement and product design concept in the United States (US). Also, Asia countries (such as China, India, and Malaysia) have made significant contributions to the research on quality product design (Tang, Zhou, Wang, Liao, & Tao, 2014; Ismail, 2015; Hassan, Ismail & Mustapha, 2012). In contrast, the Europe region (such as France, Germany) conducted 14.9% of the research in product design (Le Masson, Hatchuel, Kokshagina, & Weil, 2016).

Table 4: Author affiliations

Design Aspect	Name of Country/Region				Total
	US	UK	Europe	Asia	
Product design requirement, product design concept, detailed product design, and product design assessment.	21 (18.4%)	24 (21.1%)	12 (10.5%)	12 (10.5%)	69 (60.5%)
Product design based on computer-aided design (CAD), innovation product, and design quality.	7 (6.1%)	13 (11.4%)	5 (4.4%)	8 (7.0%)	33 (28.9%)
Other relevant aspects of design.	2 (1.8%)	0 (0.0%)	0 (0.0%)	10 (8.8%)	12 (10.5%)
	30 (26.3%)	37 (32.5%)	17 (14.9%)	30 (26.3%)	114 (100.0%)

The analysis is also based on research methodologies adopted and focused studies in the research on the development of product design. Moa et al. (2011) discussed the development of product design using simulation to produce thermal engineering design in one-dimensional (1D), two-dimensional (2D) and three-dimensional (3D) images with a multifunction CAD system. The next most adopted methods were experimental studies, qualitative and quantitative. Significant content analysis contributions were made by the author who has discussed current practices and provided future research directions (Xenakis & Arnellos, 2013; Tayal, 2013). Based on the list of reference items for this systematic review, information searching will lead to studies by the previous researcher. Thus, the researcher lists some journals and articles to aid in explaining in detail the design requirements for the production of quality products (Refer to Appendix B).

3. Discussion Towards Conceptual Model Development

Ekuan and Stewart (2000) define the design as a process to realize ideas into product shapes. The resulting product has the characteristics of aesthetics, functional and capable of solving users' problems. The design also is defined as a process of converting ideas into products that can be used by humans (Koskinen et al. 2011) with the use of scientific principles, technical information and imagination to realize the design of quality products (Jalil, 2000). Producing high-quality and innovative products depends on the designer's products (Ang et al., 2011) in tandem with creative and critical ideas. The idea to produce a product design and innovation can be triggered by brainstorming with a systematic process (Tayal, 2013). The process of designing a creative idea with the application of problem-solving methods is the most critical process because the product to be produced must meet the specifications of consumer demand (Mao et al. 2011; Sulaiman et al. 2011). Problem-solving is also emphasized by the World Design Organization (2017) in the process of designing in order to promote innovation, build success in business and lead to a better quality of life through products, systems and services. The organization also sees problems as opportunities to connect innovation (Industrial Designers Society Of America, 2017), technology, research, economic field, social and environment in developing the ideas of product design. Problem solving and creative thinking is required to provide an idea of a quality product design development process and meet the standards set (Ang et al., 2011; Ullman, 2010).

Based on the model presented by Ulrich and Eppinger (2012) and Jalil (2000), a constructed conceptual framework is shown in Figure 2. Within this conceptual framework, researchers integrate ten design process that makes four significant design process, namely: i) Product Design requirements; ii) Design Concepts; iii) Detailed Design Products; and iv) Assessment of Product Design. The four major product design processes are positioned as the entire process for the Model and Module of Product Design that will be developed and studied. The manufacturing process, the construction of the prototype and the final product are removed from the conceptual 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, colour, and usability are included in this study as guidance to the production of quality products.

The main components of the product design process in this study was adapted from the Needham's Theory of Five phases: orientation, brainstorming, structuring ideas, application ideas, and reflections (Needham & Hill 1987) to provide students in developing existing design ideas to scientific ideas in product design drawing into detailed Computer Aided Design (CAD) three-dimensional drawings. The aspects of the product design process in the industry by Ulrich and Eppinger (2012) and research on the processes of product design from previous studies (Ibrahim, 2013; Alli & Rahman, 2008; Design Council UK, 2007; British Standard Institution, 1989) are well-known in the study of quality product design. The researchers identified one component and two aspects in the product design requirements, two components and four 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.

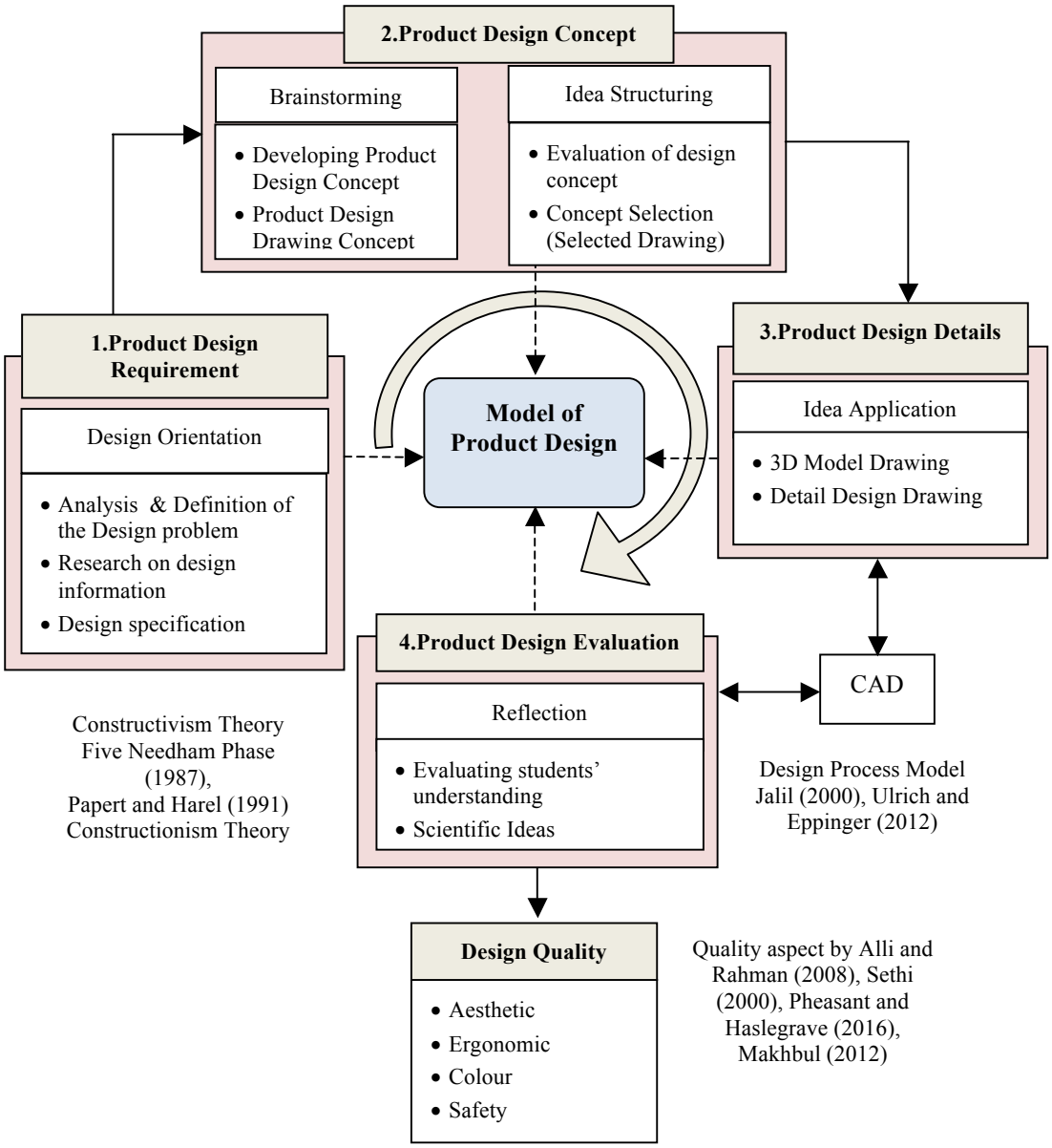

Figure 2: Research Conceptual Framework

3.1 Model and Product Design Process

There are several models related to the product design process (Alli & Rahman, 2008; Jalil, 2000; Ulrich & Eppinger, 2012; Design Council UK, 2007; British Standard Institution, 1989). However, this study uses a model developed by Jalil (2000) as the main framework in shaping the conceptual framework, and other models described above are used to strengthen the main model. Jalil (2000) in the Design Process Model stated that producing a product design is not a process that arises spontaneously, and the author has listed ten systematic design processes. The process starts with the requirement to design, analyse and define the design problems, and study the design specifications, conceptual design, production, evaluation and selection of concept, detailed design, design optimization, the production of detailed drawings and lists of materials, manufacturing, prototype construction, testing and performance improvement final and final products.

a. Product Design Requirement

The component of product design is design orientation (Needham & Hill, 1987) to provide an initial overview of the product to increase the interest of students to the products to be designed. By taking into account the initial overview of the product, the first aspect to be identified for design requirements is the analysis and definition of the design with the problems faced by users, and these were identified through a series of in-depth studies carried out by the designer (Ulrich & Eppinger, 2012). Once the problems encountered by users are identified, the second aspect is the study of specification information of product design survey related to the preliminary study of the product (Jamaluddin, Khairul Anawar & Mohd. Fadzil, 2006) in order to gain an in-depth understanding of the problems to be resolved (Jalil, 2000). The process of designing products also involves brainstorming creative ideas and troubleshooting methods (Ilevbare et al., 2013; Jin & Li, 2009) by obtaining information from various sources. Exploration, comparison and analysis of different possible product designs are also part of the requirement in designing the product (Tayal, 2013).

b. Product Design Concept

The components of design concept consist of brainstorming and structuring ideas (Needham & Hill, 1987) to raise awareness of the importance of the consumer experience with respect to product design (Bruckman & Resnick, 1995). The existing ideas owned by the student in product design can raise awareness of a new view by modifying, adding and replacing the existing knowledge and ideas with scientific value (Resnick & Ocko, 1991). These ideas are brainstormed in the minds of students in the form of visualized abstracts. The importance of brainstorming and structuring ideas for product design concepts is to trigger the design concepts through brainstorming (Ang et al., 2011), which involves critical thinking and a systematic process (Sulaiman et al., 2011). Based on the ideas identified, the next step is to sketch the concepts that are essential elements in the design process by combining visual thinking and creativity (Hussain, 2004). The idea and sketches form a concept that will be assessed through evaluation methods with a matrix based on assessment schedule, developed by Professor Stuart Pugh, known as the Pugh Concept Selection (Jalil, 2000; Ulrich & Eppinger, 2012) to obtain the final design concepts that meet specifications. Thus, based on the Assessment Schedule with the matrix, the selection of the final design concept will be translated into a selection of drawings by making improvements if necessary (Olabanji & Mpofu, 2014; Ulrich & Eppinger, 2012).

c. Detailed Product Design

The component for the detailed design of a product is idea application (Needham & Hill, 1987), which emphasizes the strengthening of abstracting new ideas about product design that was built in students' minds to be applied in the form of graphic which is the product drawings. The first aspect is a three-dimensional (3D) CAD modelling drawing (Batchelor & Wiebe, 1995; Bilalis, 2000; Osakue, 2015), which emphasizes on the production of design model to features, size, colour, surface finishing, and principal dimensions of the product (Baddam, 2014; Ulrich & Eppinger, 2012). The second aspect is a detailed drawing of the product design produced to show the details of each component. Details of each component can illustrate the essential features of products such as i) painted in scale (Hassan, Ismail & Mustapha, 2016; Osakue, 2015); ii) the important dimensions of the product (Company et al., 2015); iii) the standard drawing format as in BS308 Engineering Drawing Practice or the US ANSI Standard Y14.5M. Dimensioning and tolerancing (Quintana et al., 2010); iv) every component is labelled with the reference number of the material list; and v) list of design product materials listed in drawings (Jalil, 2000). The use of CAD software for the application of a detailed product design seems to help students in producing designs, especially in showing a product's 3D image (Allen & Pearson, 2016; Tang et al., 2014).

d. Product Design Assessment

The assessment of product design contains an aspect of reflection (Needham & Hill, 1987) that allows students to be aware of the changes that occur to existing ideas and their scientific value (Papert & Harel, 1991). This scientific value can help students when giving critical reviews and arguments in highlighting ideas regarding the design of products. The first step of the product design assessment process is to evaluate the students' understanding of the production of product design. The product designed by students in the form of detailed drawings produced by CAD (Ulrich & Eppinger, 2012) evaluated aspects of quality of design such as aesthetics, ergonomics, colour, usability and safety (Chen & Wang, 2012; Pheasant & Haslegrave, 2016). The second step is the scientific idea that emphasizes the process of moving existing abstract ideas into three-dimensional CAD drawings containing scientific elements that require creative thinking with systematic CAD instructions (Vaský et al., 2010). By the theory of constructivism, together with the existing experience, students will form a mental model of the learners who are actively designing the product and thus build their knowledge. The mental models are then used to accept new experiences (Robertson & Radcliffe, 2009; Speed, 1991).

3.2 Quality Aspect of Product Design

Aspects of design quality in the usage of quality design learning module based on CAD were also identified. The aspects of the design quality of these products are aesthetics (Sethi, 2000), ergonomics (Pheasant & Haslegrave, 2016), colour on the product, product usability and safety of the product itself (Chen & Wang, 2012; Ibrahim, 2013). The quality aspect is adopted as the guide to quality designed products through the design processes that have been mentioned above. This is because in product design, emphasis on quality is required and preferred in addition to meeting users' requirement.

a. Aesthetics of Product Design

Dieter, Suhaimi and Mohd Hazri (2008) state that aesthetics is how the product looks, feels, sounds and smells. Customer responses to this dimension are a matter of personal judgment and individual preferences (Gharakhani & Eslami, 2012). Assessment of the aesthetics of a product is therefore very subjective. Each person is different and has a view and understanding and may differ in their opinions, interests, and ideas in producing a product (Lee & Koubek, 2012). However, this situation does not affect the product. The interpretation given in connection with aesthetics refers to the features and product characteristics such as beauty, warmth, tidiness, and harmony of the function of a product (Soni et al., 2013). The aesthetic is how far the appearance of the product's design attracts the consumers to own the product (Lee & Koubek, 2010; Sethi, 2000; Xenakis & Arnellos, 2013). The critical issues affecting the aesthetic are ergonomics, i.e., designing the job to fit the worker, rather than physically forcing the worker to provide the position (US Department of Labor, 2000), and how well the design meets user's comfort (Junwu, Dongtao & Zhenqiang, 2012).

b. Ergonomics of Product Design

The concept of ergonomics has been in existence since 1700. Nowadays, ergonomics plays an essential role in improving the process of creating product design (Makhbul, 2012). Ergonomics is a broad field and includes a variety of disciplines such as psychology, physiology, biomechanics, and anthropometrics. However, in general, ergonomics mostly refers to the satisfaction and interaction between product and user, and is interpreted as the scientific study of the physical, capabilities and user criteria for the product. Ergonomics are also important in designs that are strictly related to physical products and systems or functions (Kroemer et al., 2001).

c. Colour of Product Design

Colour has its function in the beauty and value of a product (Bloch, 2011). Colour can affect the market for a product and is a primary matter in the process of designing a product (Shi, 2013). The purpose of the application of colour is to produce an atmosphere or mood to consumers. Also, the colour of the product will explain the function of a product (Ibrahim, 2013). From beverages to consumer electronics, marketers are using colour in innovative ways (Labrecque & Milne, 2012). For example, the top three colour responses successfully seen in products and branding relates to the word i.e. natural and gardening products are coloured green (nature) and televisions being predominantly black or silver (technology) (Page, Thorsteinsson & Ha, 2012).

Colours have a very significant effect on people's lives. In addition to the visual impact, colours provide different stimulations to an individual's mental and physical perceptions (Ou et al., 2004). Visual preference for a given colour should be given priority so as not to affect the product design which may then affect the marketing of products and customers' willingness to buy (Kauppinen-Räisänen & Luomala, 2010). A view confirmed by Ma et al. (2007), where the design process, appearance, style and colour presentation will ultimately be determined by the effectiveness of the implementation of the colour plan and optimization of colour design. This can help in the decision-making process and improve product performance acceptance. Thus, surfaces used in colour design should also consider the design of the product colour arrangement and the intended use of the product (Chen & Wang, 2012). During the design process, the use of 3D CAD can automatically choose the product's colour design and finalize the proposed design colour more efficiently for any product (Baddam, 2014; Tsai, Hung & Hung, 2007). The time required to produce a colour scheme by CAD is satisfactory and takes a shorter time compared to using a traditional process (Chen & Wang, 2012).

d. Safety of Product Design

The safety factor against consumer products is an element that must be prioritized to ensure it continues to gain attention and market demand. Safety is also a matter of importance during the initial design process. According to the General Product Safety Regulations (GPSR) (Viscusi & Cavallo, 1994) and The Provision and Use of Work Equipment Regulations 1992 (Britain, 1997; Executive, 2014), producers or manufacturers are required to ensure that all products are manufactured at its minimum phase regarding probability accidents and injuries. Security of the products is divided into two parts: i) protection on structures form, which is a reference to the materials used, the quality of production and product components; and ii) design security which means the concept presented will have high durability and will not cause injury or misuse (Ullman 2010). According to Norris and Wilson (1997), safety products include safety on construction products involving the use of materials, components and production quality (Sagot et al. 2003). The need

for detailed design also plays a vital role in security product design, because when there are changes to the product design, improvements will be made to the design details (Leveson, 2011). Thus, before products were designed and marketed, manufacturers are responsible in ensuring safety testing and procedures by the prescribed standards.

4. Conclusion

Product development is a process that involves a lot of consideration and decision-making on different levels. Design requirements and design concepts are viewed as high 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 with a systematic method that can generate innovation and creative problem-solving. The stage of detailed product design level can promote design concept to a product design model in graphical form 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, produce a model of quality products and meet the standards set.

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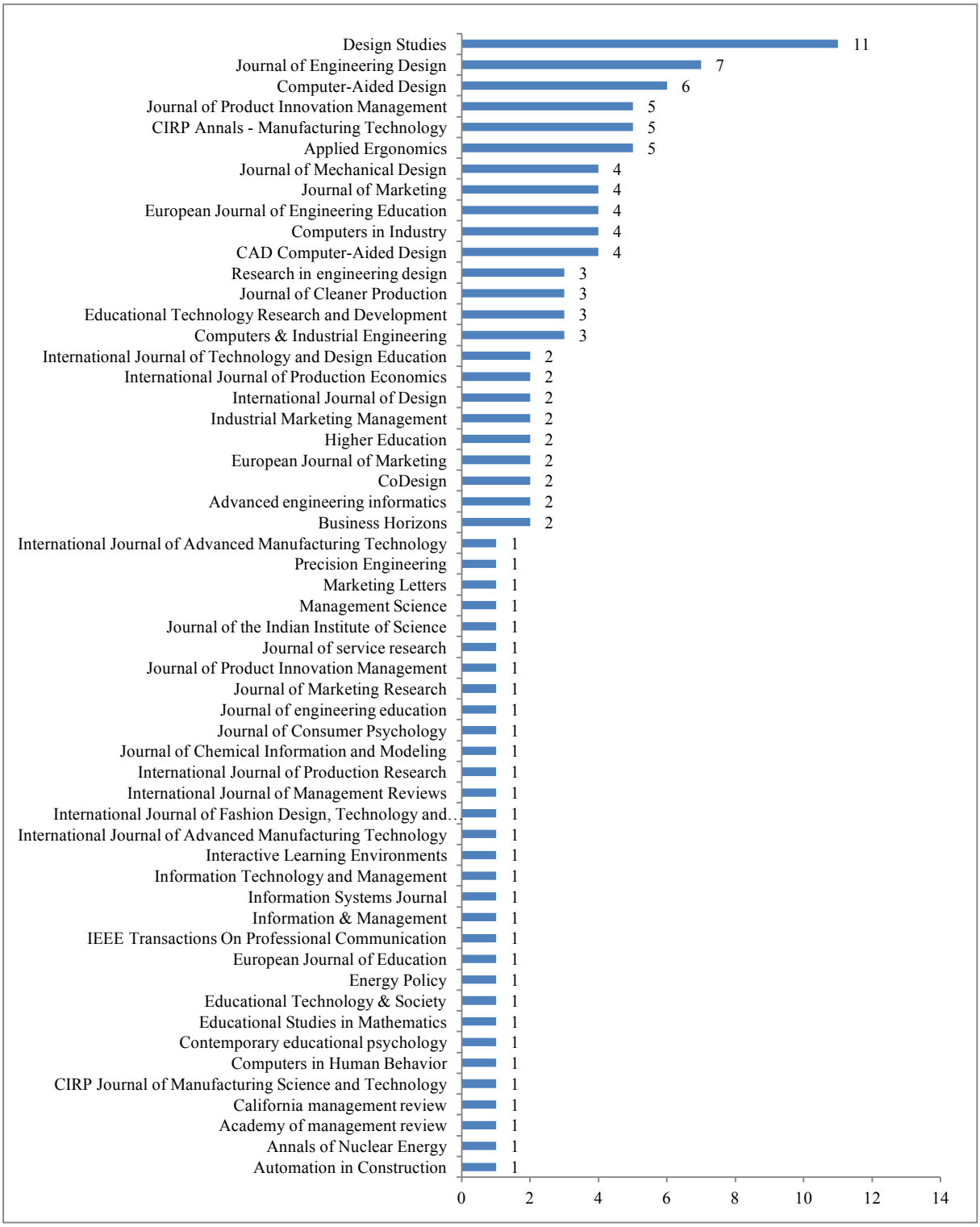
Appendix A: Number of articles referenced by name of Scopus Q1 journal rankings



Appendix B: Part of list of related research for systematic review

Researchers	Research Topic	Research Design
Ang Ng & Ghazali (2011)	Product design brainstorming using TRIZ	**Case study** systematically brainstorm a mobile table for laptop product type.
Riza Sulaiman et al. (2011)	Hip joint implants design and the usage in digital environment	**Experimental study** on 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.
Deng et al. (2014)	Color Image Evaluation for Small Space Based on FA and GEP	**Qualitative and quantitative** analysis of colour images on product design.
Lee & Koubek (2010)	Understanding user preferences based on usability and aesthetics before and after actual use	**Experiments** on simulation system of the usability and aesthetics of products by testing the hypothesis.
Olabanji & Mpofu (2014)	Comparison of weighted decision matrix, and analytical hierarchy process for CAD design of reconfigurable assembly fixture	**Assessment of analysis** using the **matrix method** to identify the conceptual design approach Computer-Aided Design (CAD) based on the requirements of usability, cost and manufacturing capabilities.
Osakue (2015)	Teaching Solid Modeling with AutoCAD	**Quantitative** research with survey method towards students experience in learning solid modeling with AutoCAD.
Ilevbare Probert & Phaal (2013)	A review of TRIZ, and its benefits and challenges in practice	**Survey** method on 40 respondents to identify the frequency and concept of TRIZ for brainstorming in designing the product. 30 of the 40 respondents indicated that 40 competitive principles in TRIZ is the most frequently used in designing the product.
Chandrasegaran et al. (2013)	The evolution, challenges, and future of knowledge representation in product design systems	**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. The aim of this study was to examine both time trends to give an understanding in creating a support tool for the design of future research.
Xenakis & Arnellos (2013)	The relation between interaction aesthetics and affordances	**Content analysis** research to form theoretical concepts related to aesthetics and interaction with the product design process.
Tayal (2013)	Engineering Design Process	**Lliterature/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.
Isham Shah Hassan et al. (2012)	Mobile and CAD Technology Integration Effects on Designing Process of Malaysian Polytechnic Architecture Student in Producing a Creative Product	**Quantitative** research to study the effects of mobile technology and CAD in the design process to produce creative products. Quasi-experimental methods were used to study the effects of the integration of mobile and CAD technology in the design process.
Baddam (2014)	Right approach to 3D modeling using CAD tools	**Survey** study to identify the effectiveness of the learning modules in solid modeling (3D) method with 92.3% of surveyors who think that the creation of geometry is much easier in this method, 84.6% were able to understand the instructions MATE better and more efficient in designing and 76.9% have high confidence level in accuracy to produce a design using 3D modeling.
Company et al. (2015)	Approach for developing coordinated rubrics to convey quality criteria in MCAD training	**Experimental** study on the feasibility of rubric criteria for the evaluation of training quality 3D CAD modelling in designing quality new products.
Chulvi et al. (2013)	Influence of the type of idea-generation method on the creativity of solutions	**Experimental** studies using method, intuitive or logical for idea generation to make creative decisions on product design. Solution for design problems using quick answer, TRIZ logic and brainstorming.
Tang et al. (2014)	Development of 2D casting process CAD system based on PDF/image files	**Product analysis** study using 2D format in PDF which contains some clearly defined drawings. Combining interactive CAD drawings storage file technology and coordinating developed PDF HZCAD2D information system.
Soni et al. (2013)	Knowledge Support System for Aesthetics in Product Design	Research on design development using the **fuzzy method. Surveys and experiments** were conducted on three products: stand mixer, coffee maker and washing machine. Research was conducted to develop support systems based on knowledge on aesthetic design for industrial products. Aesthetics characteristics studied were “cute,” “strong,” “slender” and “elegant.”
Mao et al. (2011)	A multi-disciplinary strategy for computer-aided clothing thermal engineering design. CAD Computer-Aided Design	Research on development of product design using simulation to produce thermal engineering design for apparel products in the image of 1D, 2D and 3D with multifunction CAD system.
Vaský et al. (2010)	3D Model Generation From the Engineering Drawing	**Experiment** to complete the design elements using 3D CAD. Each additional design element in the design would add a symmetric gap and increase the difficulty of the reconstruction of the 3D object. This study introduces an algorithm for 3D generating models for parts of the record rotation vector with a solid model as described by the representative of CSG.
Irwan Mahazir (2015)	Construction and testing on performance-based mobile learning prototype (MOBICAD) in Computer-Aided Design course (CAD)	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.