Utilization of Contextual Knowledge Elements in 3D CAD Model Creation From Practicing Engineers Perspective

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Abstract: In creating a new paradigm in product design, current engineers need to have a good competency in the application of Three Dimensional Computer Aided Design (3D CAD). However, the current practices shows that there is a lack of contextual knowledge among Mechanical Engineering Undergraduates and fresh graduate engineers when utilizing 3D CAD modeling software to develop a good product design. This study addresses the issue by focusing on the representation of contextual knowledge in CAD modeling which are applicable to help engineers to contextualize their 3D model product development process. The focus of this paper is to present the essential elements of contextual knowledge that have been utilized among practicing engineers in their daily design works. A transcendental phenomenological research design approach is utilized as the main framework of this study. Findings obtained from this study shows that there are three main elements of contextual knowledge emerged from this study: Realization, Design Intention and Normalization. This three elements help engineers to develop a creative and innovative product design and support them to contextualize and lead for better usability of 3D CAD software in the model creation process.
Keywords: Three Dimensional Computer Aided Design Modeling; Contextual Knowledge; Engineering Education

Introduction

Presently, computers have become well entrenched in engineering education and it is essential to evolve a beneficial pattern for their utilization. If applied prudently, computers may be a real boon to future engineers. According to accrediting bodies for engineering qualifications reported by International Engineering Alliance (Accord, 2015), attributes of engineering graduates relating to Modern tool usage, the graduate should be able to create, select and apply techniques, resources of modern engineering tools, including prediction and modeling, to complex engineering activities, with an understanding of the limitations.

As the technology changes rapidly, instructors must also keep the focus on the curriculum of the particular knowledge and skills that are required by industries (Yuen, 1990). Yuen (1990) also pointed out that, while CAD instruction is necessary to prepare mechanical engineers for industry needs, it is important to note that the CAD system is nothing more than a tool in the hands of the designer and that computers cannot draw by themselves. Aspects of Procedural, Declarative, Command and Strategic knowledge have been addressed by Lang et al. (1991), Bhavnani (2000) and Chester (2007). Most of the representations of knowledge focus on tasks related to the creation of a model on a specific type of modeling software or in other word on a single platform, but only one study has been carried out by Daud (2012) on the representations of knowledge based on users' conceptual understanding of the modeling techniques which are in general applicable to all commercially available software. Therefore, it is necessary for more research to be conducted on the types of knowledge that can be applied to all commercial 3D CAD modeling software on the market.

Similarly with other higher institutions, they are also integrating the CAD software into their Mechanical Engineering curriculum. As reported by Hamade et al. (2008) and Garcia et al. (2005), special subjects in their Mechanical Engineering curriculum and some other institutions embedded the use of the software as Engineering Design or Computer Graphics subjects (Sung et al., 2002; Devon et al., 2007). Advances in the knowledge representation in 3D CAD modeling will make the competencies of students in 3D CAD system become higher. The high competencies in the use of 3D CAD modeling system are needed when students are facing a variety of 3D CAD modeling techniques practice with different capabilities to carry out different functions in manufacturing industries.

Due to the advancement in the use of 3D CAD in the manufacturing industries and the increasing complexity of the system (Bhavnani and John, 1996), it has led to the point where contextual knowledge in developing 3D models need to be addressed. According to Lohmann et al. (2006), contextual knowledge can support user interaction and may lead to better usability of the tool. Contextual knowledge can be defined as the individual's understanding to employ specific concepts, rules and principles in the knowing of why, when and where the knowledge should be used to complete a particular task (Tennyson and Breuer, 2002; Earl, 2001; Johnson et al., 2002; Pomerol et al., 2002). Referring to the

research findings reported by Muhammed et al. (2011), contextual knowledge positively enhances the innovativeness of an individual's work and make the individual become more innovative. The enhancement of contextual knowledge will helps engineering students to be more creative that is one of the key attributes of engineers in 2020 (National Academy of Engineering, 2004).

Therefore, undergraduates should be equipped with a contextual knowledge of 3D CAD modeling techniques to ensure that they have an appropriate understanding of the utilization of the software. The presence of such knowledge from the perspective of manufacturing industries will be crucial, as the requirements are explicitly expressed by the accreditation bodies. This research will aid 3D CAD instructors in preparing students for the real world of manufacturing industries, by exploring perception of the essential contextual knowledge from practicing engineers.

This study has questioned on what are the essential elements of contextual knowledge in the application of 3D CAD modeling in creating a product design from the practicing engineers experiences and how the practicing engineers employ that essential elements in the application of 3D CAD modeling within five contexts of digital product modeling (Model Creation, Model Manipulation, Model Visualization, Model Transfer and Database and Files Management). The main aims of this study is to develop a framework of contextual knowledge that can be used to enhance the fundamental knowledge among Mechanical Engineering Undergraduates in the utilization of 3D CAD modeling software. The cognitive constructivism theory has been pinned out by researcher is to learn how practicing engineers gain their contextual knowledge and make a sense into their design works experience by utilizing 3D CAD modeling software. In this paper, the findings from the context of Model Creation will be discussed in the following section. In the model creation context, the engineer need to utilize the geometric entities such as lines, arcs, rectangle and splines to create a model.

This article is conceptually structured to introduce the significance of contextual knowledge in creation of 3D CAD model.

Conceptual Framework

This study has been guided by four appropriate frameworks known as a framework of knowledge representation in CAD modeling, framework of digital product modeling, product design specifications (PDS) framework and framework of contextual knowledge representation. The framework of knowledge representation in CAD modeling has been examined to understand the creation and utilization of knowledge across the process of creating a product model using the modeling system. Through the review on the aspect of knowledge representation in CAD modeling by researcher, aspects of Procedural (Lang et al., 1991), Declarative (Lang et al., 1991; Bhavnani, 2000), Command (Bhavnani, 2000), Strategic (Bhavnani, 2000; Chester, 2007) and Conceptual (Daud, 2012) knowledge are known to exist in the modeling process.

The framework of digital product modeling that oriented towards manufacturing operations by Yan et al. (2006) is explored to understand the prevalent tasks or activities associated with the utilization of the modeling system in the development of a product model. According to Mi et al. (2006), the modeling system has been acknowledged as leading tools in product development process. Therefore, all the prevalent tasks and activities within the context of digital product modeling approach are used for constructs development. In this study five contexts of CAD in digital product modeling that adapted from Daud (2012) conceptual knowledge framework has been focused. There are the contexts of Model Creation, Model Manipulation, Model Visualization, Model Transfer and Database and File Management. In this paper, the findings from the context of Model Creation will be discussed in the following section.

Product Design Specifications (PDS) framework by Pugh (1991) has been reviewed in this study in order to overlook on its elements application during model creation process in 3D CAD modeling. PDS is a list of the critical parameters, specifications and requirements for the designed product. Its contains with 32 elements that has been listed by Pugh (1991) and might be appear as product design specification and it is not intended to be all inclusive in one product design. In this study, the appropriate elements that can applicable in 3D CAD modeling has been chosen in order to understand the contextual knowledge elements interaction with this PDS framework and digital product modeling context framework.

The framework of contextual knowledge representation in this study has been adopted from Aspers (2006) contextual knowledge elements. There are two elements that can represent contextual knowledge and this elements are known as the lifeworld and the province of meaning. The term contextual implies direct association with cognitive skills that are defined as domain-dependent cognitive strategies (Tennyson, 1994). In order to align the used of contextual knowledge in 3D CAD modeling, researcher has defined that contextual knowledge is an individual's understanding of why, when and where to employ specific concepts, rules and principles in completing modeling activities within

digital product modeling contexts (Adnan et al., 2014). The exploration on the practicing engineers applications on the essential contextual knowledge guided by the element of lifeworld and the province of meaning element.

In this study, the lifeworld element is known as the practicing knowledge on the real problems, situations and applications face by them when they employing 3D CAD modeling activities within digital product modeling context in their product design and for the element of province of meaning is known as the practicing engineer knowledge in having same understanding on the application of 3D CAD modeling activities within digital product modeling context with others engineers in the same manufacturing firm and also they know what their customers want (Adnan et al., 2014). The structure of the conceptual framework of this study is shown in Figure 1.

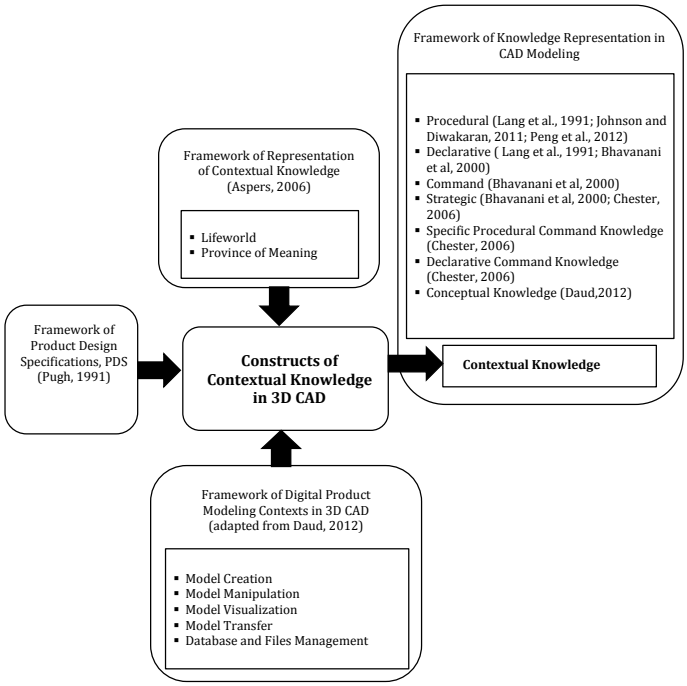

Figure 1: Conceptual Framework of Research

Research Methodology

A phenomenological research design using a transcendental phenomenology approach is the main framework of this study. Transcendental phenomenology is focused less on the interpretations of the researcher and more on a description of the experiences of participants (Moustakas, 1994). This approach has been used to explore the story of practicing engineers experienced in utilizing the elements of contextual knowledge in 3D CAD modeling application in their daily design works. Individual textural descriptions were gathered to capture what the essential contextual knowledge elements from each practicing engineer's in the application of 3D CAD modeling within five digital product modeling contexts. In addition, the structural descriptions summary details how participants employed the essential contextual knowledge elements in the application of 3D CAD modeling within digital product modeling contexts.

Practicing engineers from one Shipbuilding Company in Peninsular Malaysia has been purposefully selected. Details demography of four practicing engineers are shows in Table 1. Establishing a good rapport and building a strong power of relations with four practicing engineers are the important phase of the data collection process of this study by having a multiple in-depth interviews with them. Besides, data from participant observations and documents analysis methods are collected in enriching the final data for this study. The multiple in-depth interviews took around 2 hours in per session during their free time. The interview session has been conducted in a periodic time starting from March 2014 till March 2015. All interviews are audio recorded through electronic voice recorder. Practicing engineers also have been observed during daily working hour and recorded in observational field notes. A whole visual representation of this research operational framework is as shown in Figure 2.

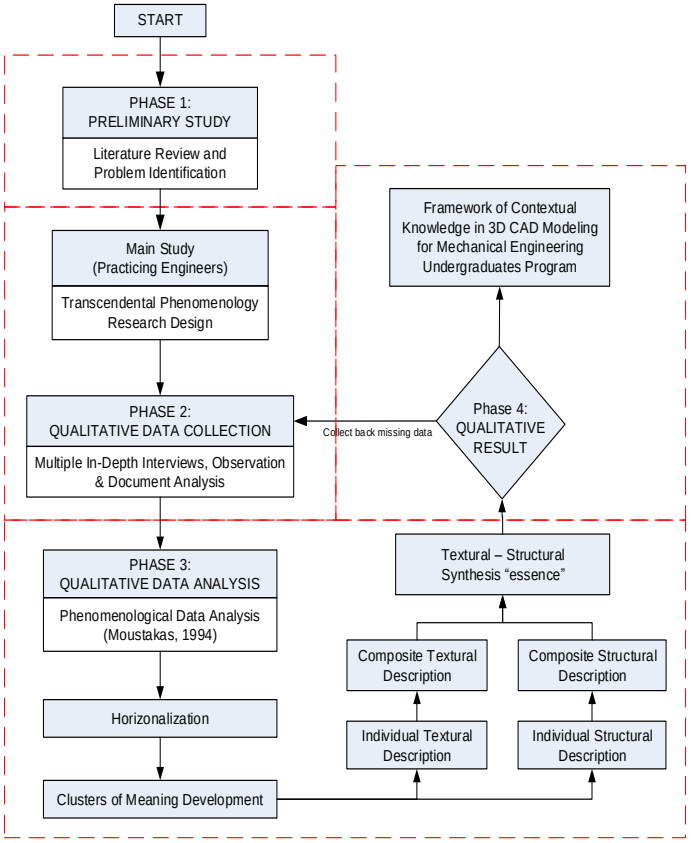

Figure 2: Visual Representation of Research Operational Framework

Table 1: Practicing Engineers Background

No.	Gender	Position in company (Technical Executive = Project Engineer)	Years of experienced in using CAD software (years)	Types of CAD software has been used	Skill level in using of CAD software (Novice 1 → 5 Expert)	Educational Background
1	Female	Senior Technical Executive	8	AutoCAD, PDMS	4	Mechanical Engineering
2	Male	Senior Technical Executive	5	AutoCAD, SolidWorks, CATIA, AVEVA	4	Mechanical Engineering
3	Male	Technical Executive	10	AutoCAD, RDM6, MAXSURF, HYDROMAX	5	Naval Architecture and Shipbuilding
4	Male	Technical Executive	4	AutoCAD, AVEVA, Maxsurf	4	Mechanical Engineering

Findings And Discussion

This paper explores the practicing engineers contextual knowledge application when using 3D CAD modeling software for creating a product design. Answers for the question of what are the essential elements of contextual knowledge in the application of 3D CAD modeling during model creation stage from the practicing engineers experiences and how the practicing engineers employ that essential elements in the application of 3D CAD modeling are discussed in this section. Three most frequent themes emerge in the application of contextual knowledge in creating model using 3D CAD modeling: Realization, Design Intention and Normalization.

Realization

In this study, realization is defined as the element that engineer need to utilize the action of the imagination to form a design that bringing something vividly to human environment. By realizing the human environment, it helps engineers to create a good model that more friendly to users and manufacturers. In Figure 3, it showed the realization elements that need to be alerted by engineer when creating a 3D CAD model.

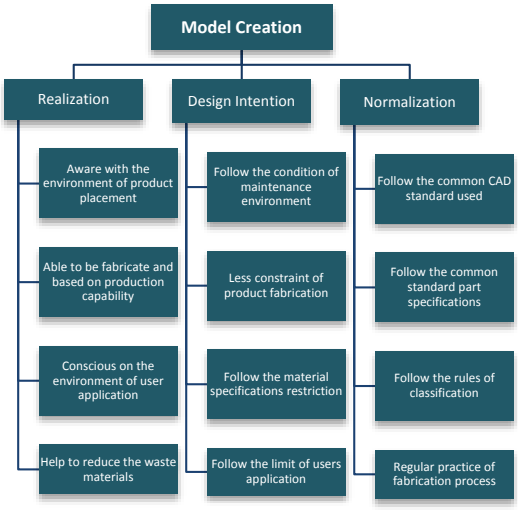

Figure 3: Visual Representation of Contextual Knowledge Elements in Model Creation Context

Create model that aware with the environment of product placement

In creating a model for product development, engineer need to aware with the environment where the product will be place. They need to make sure the model designed can be well function in the respected environment and also follow the manufacturing requirement. As mentioned by one of the practicing engineer in this study, she said that:

"…if we want to design something for equipment placement, we need to follow the manufacturing requirements for that item because we can know their maintenance space need by that item. Actually it's to make sure the design not affect the equipment performance and also that equipment can be fitting up easily and comfortable for maintenance work….we need also to understand the cabin crew working environment… "

(Practicing Engineer 1)

From the statement, it explain that when creating a model, engineer must understand the manufacturing requirement. By understanding this requirement, engineer can realize the environment of product placement.

Create model that able to be fabricate and based on production capability

As engineer, when creating a 3D CAD model, they need to know the production ability to develop their design. They need to visualize the process that involve in developing every created parts. As stated by one of practicing engineer:

"…when create a design shape for any part, we need to make sure that part can be produce or not…we need to think the process involve to create that design. If that shape is difficult to build or there is no tool or machine, we need to change to the appropriate one. So, make sure that shape is able to make by the production line…"

(Practicing Engineer 3)

According to that statement, it show that when creating a model, we need to realize the ability of fabricator to produce the product, either the ability of machines, tools or production line.

Create model that conscious on the environment of user application

During designing something that related to user application, engineer need to be conscious with the user environment. They need to consider about the product design specifications in the design such as the elements of product performance, manufacturing facility, size, weight, aesthetic, materials, ergonomic, quality and reliability, safety, company constraint, installation, environment and others elements. Here is one of the statement from practicing engineer during this study interview. He said that:

"…when create a model, we need to conscious about if design like this, what will be effect to the users…ok or not…dangerous or not…easy or not…if we choose this material for this surface, more better or not…save cost or not…we also need to consider about user application. If that user use the product without follow the procedure, that product will function properly or not…"

(Practicing Engineer 4)

Base on that statement, it showed that there are a lots of aspects or elements need to be considered by engineer when creating a model for product development. By considering that elements, actually it will helps them in creating a good 3D model.

Create model that help to reduce the waste materials

In manufacturing industries, material waste has been a major problem and difficult to control. As engineer, they need to utilize the application of CAD modeling in order to reduce the waste materials. According to interview data from one of practicing engineer, he mentioned that:

"… currently we just follow one of Korean shipbuilding company. They produce one drawing name as nesting drawing. In this nesting drawing, we can estimate the number of plate according to their size. We will arrange all the plate that need for that part in one layout. So, we can reduce the material waste and control the cost. With this drawing, we can make production operator can easily understand how many plate they need to cut and can reduce material cutting time…"

(Practicing Engineer 2)

As mentioned above, by having a good knowledge in utilizing CAD modeling to create engineering drawing, it actually can help the manufacturing industry to reduce the material waste. As engineer, they need to remember that, by controlling the material waste it will reduce the product development cost.

Design Intention

As discussed in the previous section, design intention in this study is defined as the element that engineer need to plan on how the creation part should need to be accomplish in the design development. Fig. 3 showed the essential elements of design intention.

Create model that follow the condition of maintenance environment

When designing a product, engineer need to know either the product is a portable or fixed product. If the product need to be fitted (fixed), engineer need to concern with the condition of maintenance environment of the product. In 3D CAD modeling, engineer can model and visualize the actual size and shape of the designed product. Therefore, during the model creation stage, they have to follow the maintenance space requirement in order to make sure the designed products are able to be fitted and installed easily in targeted area. From the interview, one of the practicing engineer mentioned that:

"…I try to imagine how the product will be install at that area when I design. If I try to imagine like that, I can know the problem and difficulty of person who will install our designed product. Actually we as engineer need to help them install and fitting that product easily… what I mean is more maintenance friendly…"

(Practicing Engineer 1)

Therefore, as engineer they need to make sure the 3D model has been designed follow the condition of maintenance environment.

Create model with less constraint of product fabrication

Usually there are a lots of constraints will be faced during product development process. As engineer, when in the product designing stage, they need to alert with the constraint that involved in their product design. By utilizing the application of 3D CAD modeling software, it will help engineer to reduce the constraint involved in product development. As mentioned by one of practicing engineer in this study, he said that:

"…when I create some design, I try to imagine the welding process in that design. If there is a difficult

part to weld, I try to change the design…but we need to maintain the function of product. Sometimes we still get a complaint from welder there is a part cannot be weld because very limited space…difficult to weld. So, we need to change the designed to make the less constraint one…what call, more fabricator friendly…"

(Practicing Engineer 2)

Based on the above statement, it meant that engineers need to put themselves as the manufacturer. They need to make sure their designed model is more manufacturer friendly.

Create model that follow the material specifications restriction

In product design, it iscrucial to follow the material specifications. As engineer, they need to do rigorous study on the standard requirements of product that they need to develop. One of the practicing engineer in this study said that:

"…in navy, if the part is for outdoor (outside carbine or ship) there is a standard and requirement we need to follow…so, we as designer, when model some part, we need to know that part is for outdoor use or inside the carbine and then we choose the exact material with the required thickness and dimension. Like last time I designed a platform for ship, I designed the platform surface that try make sure when navy crew do a work during rainy weather, they will not be slippery and safety…"

(Practicing Engineer 2)

From this statement, engineer need to understand the main function of product that they want to develop. After knowing the product application, they need to make sure the selected material is suitable or not with their applications. If there is a material specification restriction, they need to follow in order to make sure the product can be well function as expected. When creating model by using 3D CAD, engineer need to contextualize either the selected material is appropriate with environment of users application or not.

Create model that follow the limit of users application

By following the limit of users application actually will help engineer to produce a user friendly product. As engineer, they need to concern with the user limitation in order to make user more comfortable when using the designed product. In the stage of creation 3D CAD model, engineer need to do analysis and imagine they as the users of the product. So, they can be able to understand the limitation when using the designed product. As mentioned by one of practicing engineer in this study, she mentioned that:

"…in shipbuilding design, we have walkway standard and rule of dimension. We need to make sure the height is not above than 1.9 meter and the width is not more than 90 cm. so, when we designed something, we need to make sure this requirements is not be ignored…"

(Practicing Engineer 3)

Normalization

Normalization is the third element of contextual knowledge in 3D CAD modeling in this study. In this study, normalization can be known as the element that engineer bring the creation model into conformity within standards and requirements. Based on Figure 3, there are four aspects that need to be considered by engineer in the process of creating a product design.

Create model by follow the common CAD standard used

In CAD modeling, there are a lot types of CAD standard that usually been used. There are standard of ISO (International Standards Organization), ANSI (American National Standards Institute), JIS (Japan International Standards), DIN (German Institute for Standardization), BSI (British Standards Institute) and others. This CAD standard actually is a set of guidelines for the way CAD drawings should appear, to improve productivity and interchange of CAD documents between different offices and CAD programs. As engineer, they need to concern with the common type of CAD standard need to use when creating a 3D model. They need to set the standard for layers, dimension styles, line types, text styles and other formats. According to one of practicing engineer in this study, she mentioned that:

"…when creating a 3D CAD model, we need to make sure the standard we used is correct…we need to know about CAD standard to use…Navy standard and class to follow…and one more is shipbuilding standard. If we select a wrong standard, it will effect the appearance of our drawing…when we change the standard for dimension style, the drawing appearance will be difference…"

(Practicing Engineer 1)

Create model that follow the common standard part specifications

Commonly, in one complete product are included more than one part. There will be a custom part and standard part in one product. As engineer, they need to identify which part need to be custom made and which parts need to be used standard part. In

choosing a standard part, engineer need to understand and make sure the part specification is appropriate with their application and follow the common part used by other company. By following the standard part specification, it will reduce the cost, speed up the product development process and also make users easy to find their spare parts if have any problem. Currently, the latest 3D CAD modeling software has been provided with the library of standard part specifications. Therefore, engineer need to have knowledge in utilizing this software application in order to make a better product design. As stated by one of practicing engineer in this study, he stated that:

"…normally I will try to design a product that follow the standard part specifications rather than develop a design that have new part specifications…because if make a part with new specification, it need more cost to produce that part. Like if we create a model that need a custom size of bolt and nut, it very difficult to find a new set of bolt and nut if one of them has been lost…so, is more better we create design that use a standard part specifications…"

(Practicing Engineer 4)

Create model that follow the rules of classification

Knowing the classification of rules during the model creation stage is very important. Normally, each manufacturing area have their own rules of classification that need to be followed. As engineer, they must clear with the type of rules that need to be followed during the model creation stage. As mentioned by one of the practicing engineer in this study, she said that:

"…in shipbuilding, there are a lot of rules that need to follow and it's depend on what type of class that mention in the project contract. There are ABS class…BV class…Lloyd class…so, if in the contract want us to follow BV class for hull design, so, we need to follow all the rules and requirements in hull design…for material and welding, maybe they want us to follow ABS class, so we follow that classification rules…in one ship, maybe be there are the combination of class will be used…so, when model some design, we need to alert with the class need to be follow from the beginning until complete…"

(Practicing Engineer 1)

Based on the above statement, the correct selection of rules is crucial during the model creation stage. If the incorrect rules has been selected, it will affect the final design of created part. As engineer, when creating a 3D CAD model, they need to make sure the developed model is following the correct rules of classification according to what has been stated in project contract.

Create model based on regular practice of fabrication process

Fabrication is the stage of developing a product from the engineering drawing into real model. In this stage, a lots of process, machines and tools will be involve. As engineer, when designing the product, they need to know what are the fabrication process will be involved in their design. One of the practicing engineer in this study mentioned that:

"…after completed the production drawing, I will go directly to production site to discuss with the production engineer to confirm the designed product. Either that design can be fabricate in house or need to fabricate by sub-contractor…usually I will try to make sure my design can be fabricate in-house because it can reduce the fabrication cost…"

(Practicing Engineer 3)

From the statement, it show that the important of engineer to know the regular practice of fabrication in their company production site. Therefore, when they creating a model by using 3D CAD, they will make sure the product is possible to fabricate in-house rather than giving to outside contractors. This also can reduce production cost.

Conclusion

This paper discusses the findings of the study that explore the essential elements of contextual knowledge in the process of creating 3D model from practicing engineer experiences. Based on the present findings, three main elements of contextual knowledge emerged in this study. There are the elements of Realization, Design Intention and Normalization. These three elements play an important role in helping the engineers to contextualize their design work during the stage of creating a good 3D model for new product development. By utilizing the element of realization, it will helps engineer to utilize the action of the imagination to form a design that bringing something vividly to human environment. Therefore, the element of design intention will helps the engineer to plan on how the creation part should need to be accomplished in the design development. Furthermore, the element of normalization will bring the creation model into conformity within standards and requirements.

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