Contextual Knowledge Elements Utilization in 3D CAD Model Manipulation from the Practicing Engineers Perspectives

Article history
Received
4 December 2022
Received in revised form
16 December 2022
Accepted
18 December 2022
Published online
20 December 2022

Mohd Fahmi Adnan[a*], Muhammad Sukri Saud[b], Mohd Fadzil Daud[c]
[a,b] Faculty of Social Sciences and Humanities, Universiti Teknologi Malaysia, Skudai, Johor, Malaysia
[c] Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, Skudai, Johor, Malaysia
**mohdfahmi.adnan@utm.my*

Abstract

Engineers' ability to contextualize their created 3D CAD model during the design stage is the most important aspect of product design. In this conducted research, researcher has found that there was a lack of contextual knowledge among Mechanical Engineering Undergraduates and fresh graduate engineers in utilizing Three-Dimensional Computer Aided Design (3D CAD) modeling software in developing a good product design. In addressing this issue, a study has been conducted to focus on the representation of contextual knowledge elements in 3D CAD modeling applications. This article focused on presenting essential elements of contextual knowledge utilized among practicing engineers in their daily design works, in the aspect of Model Manipulation. Transcendental phenomenology approach has been utilized as the main research methodology. Four practicing engineers from engineering department of one shipbuilding company in Peninsular Malaysia were purposively selected to be studied. From the analysis, there are three most frequent emerging themes in the application of contextual knowledge in manipulating model using 3D CAD modeling: Realization, Design Intention and Normalization. These three elements play an important role in helping engineers to contextualize their design work during the stage of manipulating created model for new product development process.

Keywords: Three-Dimensional Computer Aided Design Modeling; Contextual Knowledge; Engineering Education

Introduction

Recently, many studies have been conducted on improving the engineering undergraduates' contextual competencies level (Beena and Suresh, 2022; Bell et al., 2019; Kyoung Ro et al., 2017). Having a good level of contextual competence helps to improve individual understanding and establishing their place in the profession in engineering design work (Engineering Accreditation Commission, 2018). The importance to promote contextualization ability among engineering undergraduates in engineering practice also has been stressed in the ABET program accreditation under the criteria of 3.c, 3.f, 3.h and 3.j (Engineering Accreditation Commission, 2018). According to Grasso and Burkins (2010) in their book "Holistic Engineering Education," the advancement of contextual knowledge in 3D CAD modeling can also improve engineers' ability to develop creative and innovative product designs.

However, based on conducted structure interviews in the preliminary study, results have shown that there was lack of contextual knowledge in the applications of 3D CAD modeling among Mechanical Engineering undergraduates and fresh graduate engineers. Due to this lack of knowledge, product designers are unable to contextualize their produced models in order to build a successful product design for users and manufacturing applications. According to Ma and Zhang (2010), product designers frequently commit a number of mistakes. During the design stage, the focus is typically on the function of the product rather than the manufacturability of the parts, which has resulted in the inability to manufacture some components. By considering the manufacturing constraints throughout the product design phase, numerous issues can be avoided (Nguyen and Martin, 2015).

Therefore, this study was conducted to enhance engineering students' contextual knowledge in the application of 3D CAD modelling software in engineering design tasks and to advance the engineering education reformation movement. The main aim of this study is to construct a framework of contextual knowledge that can be utilized to improve the fundamental knowledge of Mechanical Engineering undergraduates in the application of 3D CAD modeling software. The questions of 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 the essential elements in the application of 3D CAD modeling within the four contexts of digital product modeling (Model Creation, Model Manipulation, Model Visualization and Model Transfer) are answered in this study. In this article, the finding of the essential

Adnan, M. F., Saud, M. S., Daud, M. F. (2022), Contextual Knowledge Elements Utilization in 3D CAD Model Manipulation from the Practicing Engineers Perspectives, *ASEAN Journal of Engineering Education*, 6(2), 43-53.

contextual knowledge elements in Model Manipulation process that have been utilized among practicing engineers in their daily design work are presented. This article is conceptually structured to present the significance of contextual knowledge in learning 3D CAD modelling and, as a subsequent step, to inform the engineering education community about the presence of contextual knowledge in the process of 3D CAD modeling.

Contextual Knowledge in 3D CAD Modeling

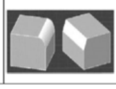
The individual's level of success in completing the engineering design task is dependent on the amount of information that is stored in their cognitive mind (Adnan, 2021). In order to provide a solid theoretical foundation for the research that was conducted, the cognitive constructivism theory was selected as the appropriate theoretical framework. The cognitive constructivism theory emphasizes the importance on the mental processes people utilize in order sense of their surroundings (Kaufman, 2018; Amineh and Asl, 2015). Declarative knowledge, procedural knowledge, and contextual knowledge are the three categories of knowledge existed in the field of education (Ubbes and Njoku, 2022; Ubbes, 2008; Tennyson and Breuer, 2002.

In this study, contextual knowledge was investigated based on the difficulty described in the preceding section. According to Tennyson and Breuer (2002), contextual knowledge is an individual's understanding of how to apply specific concepts, rules, and principles in the context of knowing why, when, and where the knowledge should be applied to fulfil a specific task. Aspers (2006) stated that there are two main elements to represent contextual knowledge: lifeworld and province of meaning. The lifeworld is referring to the lived and experienced world and thus, it is something more than the world itself rather than the subject itself (Aspers, 2006). The province of meaning refers to the understanding the meaning of a picture or seeing it in the same way that someone else does is a result of shared experiences, schooling and other similarities (Aspers, 2006). These two elements are crucial for solving the real-world problems and the role of contextual knowledge is to help an agent behave quickly, automatically and appropriately for its current problem-solving situation (Brézillon, 1999).

Contextual knowledge in 3D CAD modeling has been identified as an individual's understanding of why, where and where to use the essential lifeworld and province of meaning elements in 3D CAD modeling activities within four digital product modeling contexts: model creation, model manipulation, model visualization and model transfer. As mentioned before, lifeworld and province of meaning are the two main elements of contextual knowledge. These two elements have been adapted for this study in exploring contextual knowledge among practicing engineers. Therefore, these elements are redefined into the contexts of this study. The lifeworld element in this study is known as the practicing engineer's knowledge on the real problems, situations and applications face by them when applying 3D CAD modeling activities within four digital product modeling contexts in their product design (Adnan, 2021). For the element of province of meaning, it has been defined as the practicing engineer's knowledge in having same understanding on the application of 3D CAD modeling activities within digital product modeling context with other engineers in the same manufacturing firm. In addition, they know what their customers want (Adnan, 2021).

In the manufacturing industry's real design world, these two elements actually play an essential role when the engineer wants to design a product by using any 3D CAD modeling software. Table 1 shows the applications of contextual knowledge elements in the 3D CAD modeling process. For example, when the engineer wants to design a product that embed safety element. The engineer needs to think before he or she designs the product by using 3D CAD modeling software in order to make sure the final product can be workable and safe to use by the users. Usually, in 3D CAD modeling, the activity like fillet or chamfer will be involved in every sharp edges area in the product in order to develop a safety product to the users.

Table 1. Contextual Knowledge in 3D CAD Modeling Process

Modeling within the Contexts	Modeling Activities	Lifeworld	Province of meaning
Safety	▪ Fillet ▪ Chamfer 	?	?

Based on the findings of the preliminary interview with a practicing engineer in one of the manufacturing industries, that engineer admitted that he had made a lots of mistake when he was tasked to design a ferry toilet. As a consequence of his design errors, his company had to bear substantial loss. This mistake happened because his design does not think about the ferry users' application. He does not put himself as the user of the toilet and this has caused him not to be able to think about what would happen to the users when they use the toilet while the ferry is moving or in other situational context. These problems actually relate to what has been reported by Ma and Zhang (2010) in their study. They have reported the most frequent mistakes that are commonly made by product designers in manufacturing industries. There were mistakes that caused some designed parts not to be ably machined during the manufacturing stage.

These mistakes occurred mainly because the designers considered more on the product function rather than the aspects of product manufacturability.

Therefore, the essential elements of lifeworld and province meaning when the practicing engineers want to design by using 3D CAD modeling need to be explored in this study.

Model Manipulation in 3D CAD Modeling

This research focused on the representation of contextual knowledge in CAD modeling, which can be used to assist engineers in contextualizing their 3D models during the product design process. Yan et al. (2006) digital product modeling framework that is directed toward manufacturing operations is investigated in order to fully understand the common tasks or activities associated with the use of the modeling method in the creation of a product model. The framework of digital product modeling used in this study has been adapted from conceptual knowledge in the 3D CAD modeling framework by Daud (2012). According to Daud's framework, the constructs of Model Creation, Manipulation, Exploratory Visualization, Model Transfer and Collaboration have been explored to understand the conceptual knowledge applications in 3D CAD modeling.

In this study, four constructs of the framework have been adapted and redefined to make it applicable to the context of this study. There are the constructs of Model Creation, Model Manipulation, Model Visualization and Model Transfer. These four constructs actually represent the standard process involved in the application of 3D CAD modeling software. Figure 1 shows the cycle of these four constructs utilization in the process of product design development in 3D CAD modeling. According to McEwan and Butterfield (2011), the integration of all design aspects provides a complete digital product modeling platform. These integration aspects have allowed the downstream life cycle phases like testing and certification, maintenance and operation and the disposal integration aspect need in the conceptual design process.

Since manipulation is one of the most critical activities during the model creation process, it is viewed separately from the model creation context to emphasize the relative importance of the contextual knowledge involved. In this model manipulation context, the study is focused on the system understanding and utilizing in performing the manipulation tasks in producing the alternatives and preferred solution. The activity of manipulating the modeled object needs to be involved in this model development process. Silva and Chang (2002) and Khan et al. (2018) state that the process of modeling the product design commonly involves frequent design changes. In addition, Silva and Chang (2002) added that the design changes complexity increases due to the design process need to involve various engineering disciplines.

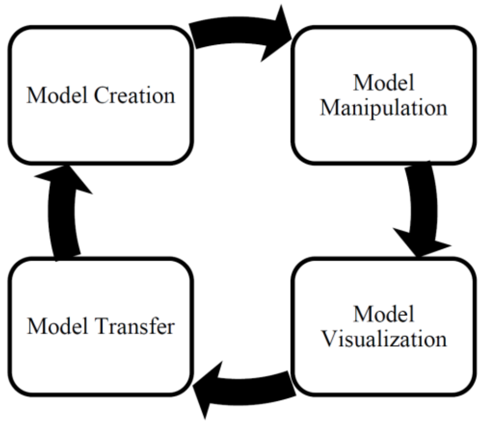


Figure 1. Process Involve in Product Design Development in CAD

Vajna et al. (2020) and Hovarth et al. (2004) stated that the advancement in the customer-oriented product design process necessitates repeated modeled object modification. In further, Hovarth et al. (2004) have explained that engineers gain built-in knowledge from the existing models during the product development and modification stages. This knowledge helps to prevent the quality of model from being deteriorating for future applications and modifications. Since design is an iterative process, Lee et al. (2008) have mentioned the need for product designers to explore and experiment with the alternative design when they are in the early stages of developing a new product design. In addition, Lee et al. (2008) highlighted that applying this approach actually can help the product designers to identify the best design options by using the best-known solutions.

Product modification and diversification have made manipulation activities an important task in 3D CAD modeling due to recent advancements in the product development process (Daud, 2012). Chu et al. (2009) emphasized the importance of such activity in their study. They demonstrate how to use manipulation tasks in a 3D CAD modeling system in modifying product design. By modifying the parts combination, the assembly form selection and the assembly sequence rearrangement, these approaches allow for the automatic generation of 3D product variations structures. According to Yoshimura (2010), the use of rapid prototyping technologies in conjunction with 3D CAD systems has equipped product designers with advanced support for manipulating realistic manufactured models.

In this model manipulation context, the proper utilization of 3D CAD modeling features would boost innovation and aid in problem-solving of practicing engineers during the process of product design development. Having a good competency in the process of modifying design ideas extremely helps the designers to reduce the amount of time spent and also allowed for a quicker design manufacturing process (Mehta, 2020; Wang et al., 2009; Visser, 2006). In creating the desired product design, CAD features technology has been proved as an effective tool in manipulating the shapes of the created model. Wang et al. (2009) provide an example of this type of facility by stating that any modifications made to any part or assembly are automatically generated in all associated parts and drawing sheets, resulting in all relevant files being modified simultaneously when the main part is manipulated. According to Daud et al. (2012), the final shape of the created model can be manipulated by modifying the geometry or features of the part. In order to achieve a rich diversity of design variations, this context has been explored in this study in order to contextualize the manipulation activity within the context of 3D CAD modeling process among practicing engineers in the manufacturing industry.

Research Methodology

This research was carried out using a transcendental phenomenology research design to explore the story of practicing engineers experienced in utilizing the elements of contextual knowledge in 3D CAD modeling application in their daily design work. This approach enables the researcher to emphasis more on the description of the practicing engineers' experiences and less on the researcher's interpretations. Four practicing engineers from a Peninsular Malaysian shipbuilding company were selected using a homogenous sample approach (Creswell and Guetterman, 2019; Patton, 2015). This selection allows for an in-depth and representative exploration of the contextual knowledge of practicing engineers in developing 3D CAD models. This study's selection of practicing engineers as respondents is limited to samples with at least three years of daily work experience using 3D CAD modelling software. As suggested by the Engineering Accreditation Commission (2018), a professional engineer in their specialty must have three years of practical experience.

The concept of data saturation has been utilized in this conducted study. The saturation stage has occurred when there are no new themes emerged with the fourth practicing engineer and he has repeated the same information as the previous engineers. Even though there are only four respondents has been explored in this study, Lincoln and Guba (1985) and Corbin and Strauss (2014) stated that this sample is considered to be sufficient for a qualitative phenomenology study as long as it can provide an understanding of the exploration phenomenon from those respondents. According to Dukes (1984), he recommends to study three to ten persons in one phenomenological research. This recommendation has also been supported by Smith et al. (2009) and they suggested to the novice researcher to conduct at least three and above respondents for the phenomenology study.

Table 2 shows the demographic information of the four practicing engineers participated in this exploration study. Husserl's concepts of epoche (or bracketing) were used to capture a good description of the experiences of practicing engineers in this study: "put aside personal experiences as much as possible and take a fresh look at the phenomena under investigation in this study" (Creswell and Poth, 2018). A series of phenomenological interviews and document analysis were used to acquire the data for this study. During their free time, each session of the phenomenological interview lasted around one and a half hours. Started in March 2014 and continuing until March 2015, the interview session was done periodically in four series. During interview sessions, the Moustakas (1994) standards for phenomenological interviews were followed. According to Kennedy (2010), conducting a phenomenological interview requires the researcher to keep the questions open and devoid of preconceived concepts and leading phrases, allowing for a more interviewee-guided, rich narrative of a phenomena.

Table 2. Practicing Engineers Background

No. of Practicing Engineers	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

Then, interviews data were analyzed using the Stevick-Colaizzi-Keen modification phenomenological analysis method by Moustakas (1994). This phenomenological analysis was chosen based on the underpinning process of this analysis that has helped the researcher to answer the research questions of this study and allowed the researcher to capture rich descriptions of the participants' experiences. The analysis began after all the interviews data has been transcribed. All the interviews' transcriptions then were continued with the horizonalization analysis process to find significant statement from each practicing engineers (Moustakas, 1994). From the analysis process, 28 significant statements that related to the utilization of contextual knowledge in 3D CAD model manipulation have emerged from the horizonalization process. Then, all listed significant statements were used to construct the textural descriptions to capture on what are the essential contextual knowledge elements from each practicing engineers in the application of 3D CAD model manipulation contexts. Subsequently, structural descriptions were formed to summarize details on how practicing engineers employed the essential contextual knowledge elements in the application of 3D CAD model manipulation contexts.

In forming the main theme of this study, the textural and structural descriptions were integrated to provide a synthesis of the meanings and essences of the practicing engineers' experience. Relevant documents such as printed engineering drawing, drawing standard and guidelines were also collected from the engineers as supported data to increase the reliability of the interview findings. A whole visual representation of this operational research framework is shown in Figure 2.

Research Findings and Discussion

This article presents the findings from the exploration of the practicing engineers' contextual knowledge application when using 3D CAD modeling software to create 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 manipulation stage from the practicing engineers' experiences and how the practicing engineers employ those 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 manipulating a model using 3D CAD modeling are: Realization, Design Intention and Normalization. Figure 3 showed the sub-elements that emerged on each theme that needs to be contextualized by engineer when manipulating a 3D CAD model.

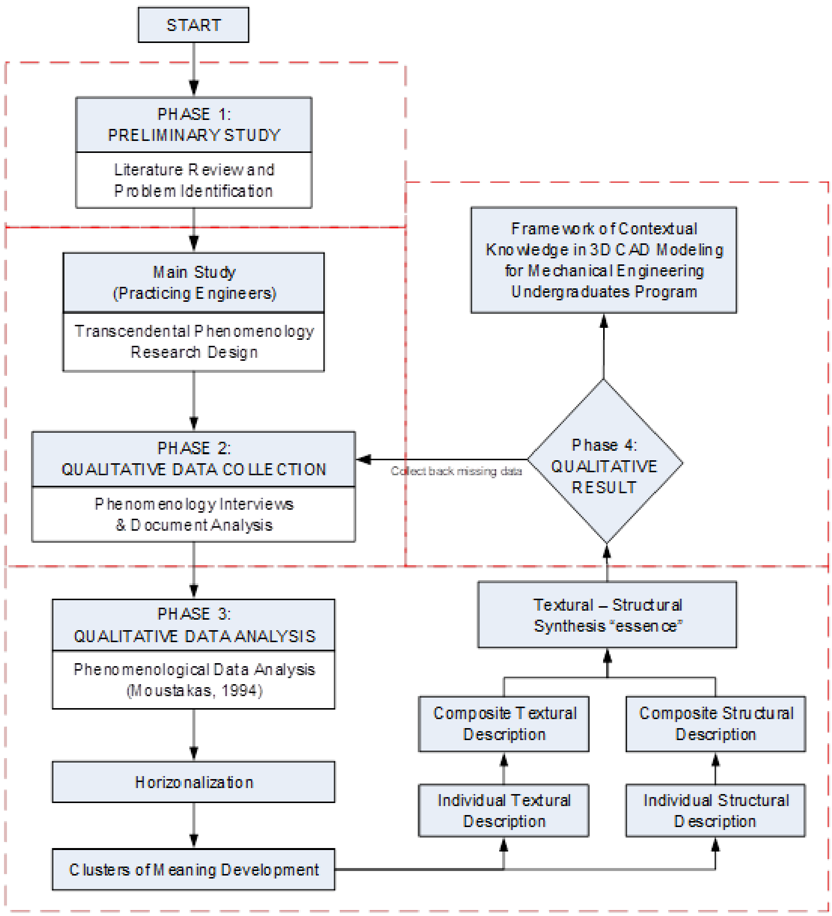


Figure 2. Visual Representation of Research Operational Framework

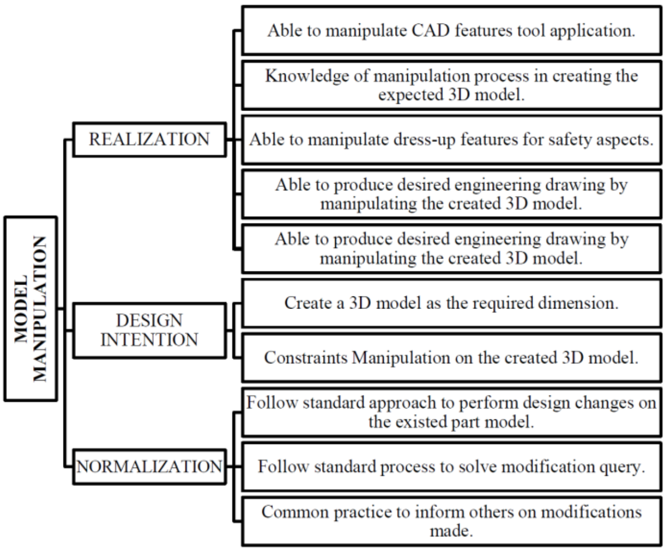


Figure 3. Contextual Knowledge Elements in Model Manipulation

Detailed definitions of these three contextual knowledge elements emerged from this study are explained in Table 3.

Table 3. Summarize of Contextual Knowledge Elements Definition in Model Manipulation Context

Contextual Knowledge Elements in Model Manipulation Context	Definition
Realization	Element that the engineer needs to utilize the action of the imagination to manipulate the created product design that was bringing something vividly to the users' or manufacturers' application.
Design Intention	Element that the engineer needs to plan on how to employ the manipulation process on the created part design during the product design development stage.
Normalization	Element that the engineer brings the creation model into conformity with standards and requirements after performing the manipulation process.

Realization in Model Manipulation

In this study, realization is defined as the element that the engineer needs to utilize the action of the imagination to manipulate the created product design that was bringing something vividly to the users' or manufacturers' application. By realizing the users' or manufacturers' applications can help the engineers to create a good model that is more friendly to users and manufacturers' sites. They need to be able to manipulate CAD features tool application, knowing the manipulation process in creating the expected 3D model, able to manipulate dress-up features for safety aspects, able to produce desired engineering drawing by manipulating the created 3D model and able to manipulate 3D CAD model for exploring created design.

Able to manipulate CAD features tool application. The engineer's ability to manipulate all the provided CAD modeling features has been highlighted during the researcher exploration on the practicing engineers experienced in the model manipulation stage. This element has been emphasized by them as a vital element to helps the engineer in the process of creating the desired product design. According to Ault and Phillips (2016) and Doutre et al. (2017), this element has played an important role in making the engineer achieved to model their desired design shapes.

As been said by Jost et al. (2020), generally, to form a complete 3D model, the engineer needs to utilize various CAD features. This statement actually was aligned with what has been said by most of the practicing engineers from this study. Since there was more than one CAD modeling software have been experienced among them, they have highlighted the importance of engineer to have an ability to transfer their previous knowledge in utilizing the CAD modeling features during the model manipulation stage. The work on CAD features knowledge transfer has been explored by Guidera (2004) in his research study.

Knowledge of manipulation process in creating the expected 3D model. This element has been emerged by the practicing engineers when they tried to relate the features tools application in creating the desired product design. Based on the findings, most of them have mentioned the impact of knowing the manipulation process during the model creation stage. The works by Hudson et al. (2012) have discussed the implication of engineers for having good knowledge in the manipulation process for creating the desired product design.

According to practicing engineers' experiences, by realizing the manipulation process will help the engineer to plan the desired features tools that need to be utilized in creating the expected product design. As mentioned by Cohen et al. (2019), the intensive manipulation process helps the engineer to transform the ideas generation into the desired 3D CAD model. Therefore, as engineers, they need to realize which manipulating process needs to be performed to speed up their ability to create the expected 3D model (Bordegoni and Rizzi, 2011).

Able to manipulate dress-up features for safety aspects. Based on the findings, this element has been emerged by practicing engineers in creating a good product design. They have emphasized the importance of engineers to have the ability to manipulate the dress-up features for making the created product design safer for the user applications. This element also has been highlighted by Kamdar (2015) in his study on designing and manufacturing of wheel for the magnetic climbing robot.

Referring to the practicing engineers experienced, the dress-up features like fillet or chamfer are the most common features been used on the critical part during the product design. These dress-up features also have been used as the standard features that commonly been used by other engineers during the 3D CAD model creation (Agarwal et al., 2018; Kamdar, 2015).

Able to produce desired engineering drawing by manipulating the created 3D model. The engineer's ability to produce the engineering drawing for product development is one of the essential elements emphasized by practicing engineers in this study. The findings show that most of the practicing engineers agreed that the CAD system had helped them a lot to produce a required engineering drawing for product development. According to Kasik et al. (2005), by fully utilizing the CAD system will help the engineer to produce a good engineering drawing for production site applications. Good engineering drawing actually can help the production site to positively interpret the shape, information and requirements of the created product design (Simmons and Maguire, 2012; Dobelis et al., 2012; Kasik et al., 2005).

Therefore, the engineer needs to fully manipulate the created 3D model to produce a good engineering drawing for product development applications. Based on the findings, practicing engineers have realized that the applications of features tool in the recent CAD modeling software to speed up the process of creating needed engineering drawings from the created 3D model. Gaddam (1995) has mentioned that a good utilization of CAD modeling software helps the designer transform the 3D model into a desired engineering drawing.

Able to manipulate 3D CAD model for exploring created design. The practicing engineers had highlighted this element when they shared their attractive experienced when using CAD modeling software. They have shared their experiences in utilizing the 3D model exploration features tools. In the recent CAD modeling software, the 3D model exploration features tools have been equipped to help the engineer explore their created model during the model creation stage. According to Rodriguez (2015), 3D model exploration is the process of manipulating the created 3D model by interacting with the 3D content to visualize the model from any angle and making the part model analysis.

Based on the findings, the practicing engineers have shown the ability to explore their created model by making the part model manipulation. They have made the part model analysis, applied the orbit rotation tools to view the part model from a different angle and making the 3D model simulation to make sure their created part is functional and workable design. Making a functional and workable product design is the most crucial aspect that engineers need to emphasize during the part model manipulation process (Park et al., 2019; Ope-Tairu, 2016).

Design Intention in Model Manipulation

In this Model Manipulation context, the design intention is defined as the element that the engineer needs to plan on how to employ the manipulation process on the created part design during the product design development stage. By contextualizing the intention of the created part design, it will help the engineer to speed up the process of product development. They need to create a 3D model as the required dimension and knowing the constraints manipulation on the created 3D model.

Create a 3D model as the required dimension. In the process of creating and manipulating the part model, this element has been highlighted as the crucial element by the practicing engineers in this study. They have stated that all the design part needs to follow as what the size requested by the clients or customers. According to Louie (2018), there is a must of an engineer to make sure the final dimension of the parts as the customer needs. He added the engineer need to put this aspect as the main requirement that needs to be followed and achieved during the part modeling stage. If the engineer cannot achieve this requirement, commonly, it will affect the expected function of the created product (Prats, 2007).

Based on the findings, practicing engineers have also highlighted the importance of engineers to ensure all the required dimensions are inserted or shown in the produced engineering drawing. They have emphasized that this aspect is vital in order to help the production site develop the created product design as required. Other researchers have also emphasized this aspect in their research works (Henderson, 2014; Henderson and Swaminathan, 2003).

Constraints manipulation on the created 3D model. In the stage of manipulating the created model, the practicing engineers in this study have emphasized this element as the essential elements that need to be alert by the engineer during the model development stage. The exploration of this constraints manipulation in 3D CAD modeling has been done by Hartman (2005) in his research study. Based on the findings, there were two types of constraints that have been mentioned during the exploration of constraints manipulation in part model development.

There are geometric constraints and dimensional constraints.

Cai et al. (2020) have defined geometric constraints as a geometric relationship between two shapes that affect the relative constrained shape transformation with the fixed shape. The applications of these geometric constraints in CAD modeling can be explored in Perzylo et al. (2015). For the dimensional constraints, Hanratty (1995) has defined these constraints as the constraints that have been used to control the geometry through large shape variations. As mentioned by practicing engineers in the findings, these two constraints need to be well manipulated in order to create the expected part model design. Therefore, the engineer's fundamental understanding on the application of these two constraints during the model development stage needs to be contextualized in order to speed up the process of designing the part model (Hartman, 2005).

Normalization in Model Manipulation

In this Model Manipulation stage, the normalization is defined as the element that the engineer brings the creation model into conformity with standards and requirements after performing the manipulation process. By contextualizing the common manipulating activities during the model manipulation stage, it will help the engineer to speed up the process of product development. Figure 2 shows the normalization elements that the engineer needs to emphasize when manipulating a 3D CAD model. They need to create a model that follows the standard approach to perform design changes on the existed part model, follow standard process to solve modification query and the common practice to inform others on modifications made.

Follow standard approach to perform design changes on the existed part model. In performing design changes or modifications on the created part model during the process of product development, the practicing engineers in this study have emerged this element as a vital element that needs to be followed in their company practiced. Based on the previous chapter's findings, all the engineers in this study have mentioned the existence of the Site Technical Query (STQ) form as the standard of practice in performing design changes during product development. The conceptual understanding in performing the CAD design changes among the practicing engineers has been explored by Daud (2012). In this study, the practicing engineers have also highlighted this element's existence by contextualizing the standard of practice on implementing this element in their daily design works.

According to the works by Kang et al. (2019), there were a lot of approaches have been practiced by manufacturing industries in performing the design changes during the process of product development. Kang et al. (2019) have summarized the list of the standard of practice regarding to this element. The implementation of this element actually helps the companies to standardize all their design changes work has been performed during the product development process and updating the recent changes has been made by the engineer.

Follow standard process to solve modification query. This element is related to the previous emerged element. It was more focused on solving the process of modification query made during the product development process. Based on these element findings, the practicing engineers of this study have highlighted the importance of the engineer in understanding the problem category before proceeds with the solving process for the problem. This was due to the standard of practiced needs to be followed to solve the modification query by the production site. According to the research study by Hack et al. (2010), they have found that there were many approaches and standards of practice have been utilized by the manufacturing industries in managing the modification query.

Based on the findings, the problem categories can be divided into three types of problems either the query of dimension modification or the shape design changes or the request for material changes. After clearly understand the problem and the category of the problem, the engineer needs to plan and take action to solve the modification query based on their company standard of practice. The approach to solving the CAD design modification query also has been discussed by Pratt and Anderson (2000) in their research study.

Common practice to inform others on modifications made. After any modification has been made on the created part design, the practicing engineers in this study have explained their common practice in informing others about the modification that has been made. Based on the findings, there were many common approaches have been made by practicing engineers in this study. Commonly they will update the drawing revision number, adding the cloud mark on the changes area of the part, adding description notes on the title block notes section and other approaches. Most of the common approaches that emerged from this study are similar to the other companies' practices. As reported by Chen and Siddique (2005), after performing the design changes on the created part, the approach like adding the arrow with the dark box ends to represent the modification that has been made in the drawing is needed by the engineer. Based on work by Akcamete et al. (2008), they have highlighted the importance of engineers to apply a systematic method for tracking the changes and updating the design changes in the engineering drawing. This was due to the lack of updated information on design changes received by the downstream during the process of product development.

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 from 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 help engineers to utilize the action of the imagination to manipulate the created product design that was earlier on vividly clear to the users' or manufacturers' application. Therefore, the element of design intention will help the engineer to plan on how to employ the manipulation process on the created design part during the product design development stage. Furthermore, the element of normalization will bring the creation model into conformity with standards and requirements after performing the manipulation process.

Acknowledgement

The authors wish to thank the Centre for Engineering Education (CEE) UTM, for supporting this research project.

References

Adnan, M. F. (2021). *A Framework of Contextual Knowledge in Three Dimensional Computer Aided Design for Mechanical Engineering Undergraduates.* (Doctoral dissertation, Universiti Teknologi Malaysia).

Adnan, M. F., Daud, M. F., & Saud, M. S. (2014). Contextual knowledge in three dimensional Computer Aided Design (3D CAD) modeling: a literature review and conceptual framework. In *2014 International Conference on Teaching and Learning in Computing and Engineering* (pp. 176-181). IEEE.

Agarwal, D., Robinson, T. T., Armstrong, C. G., Marques, S., Vasilopoulos, I., & Meyer, M. (2018). Parametric design velocity computation for CAD-based design optimization using adjoint methods. *Engineering with Computers*, *34*(2), 225-239.

Akcamete, A., Akinci, B., & Garrett Jr, J. H. (2008). Towards a formal approach for updating building information models. In *5th International Conference on Innovation in Architecture, Engineering and Construction*.

Amineh, R. J., & Asl, H. D. (2015). Review of constructivism and social constructivism. *Journal of Social Sciences, Literature and Languages*, *1*(1), 9-16.

Aspers, P. (2006). Contextual Knowledge. *Journal of Current Sociology*. *54*(5), 745-763. DOI: 10.1177/0011392106066814.

Ault, H., & Phillips, A. (2016). Direct Modeling: Easy Changes in CAD? *In Proceedings of the 70th ASEE Engineering Design Graphics Division Midyear Conference* (pp. 99–106).

Beena, B. R., & Suresh, E. S. (2022). Analysis of learning outcomes of Civil Engineering students of Kerala state using dimension reduction Techniques. *Journal of Engineering Education Transformations*, *35* (Special Issue 1).

Bell, S., Chilvers, A., Jones, L., & Badstuber, N. (2019). Evaluating engineering thinking in undergraduate engineering and liberal arts students. *European Journal of Engineering Education*, *44*(3), 429-444.

Bordegoni, M., & Rizzi, C. (Eds.). (2011). *Innovation in product design: from CAD to virtual prototyping*. Springer Science & Business Media.

Brézillon, P., & Pomerol, J. C. (1999). Contextual knowledge sharing and cooperation in intelligent assistant systems. *Le travail humain*, 223-246.

Cai, C., Liang, Y. S., Somani, N., & Yan, W. (2020). Inferring the Geometric Nullspace of Robot Skills from Human Demonstrations. In *2020 IEEE International Conference on Robotics and Automation (ICRA)* (pp. 7668-7675). IEEE.

Chen, Z., & Siddique, Z. (2005). A Cooperative-Collaborative Design System for Multi-Disciplinary Mechanical Design. In *International Design Engineering Technical Conferences and Computers and Information in Engineering Conference* (Vol. 47403, pp. 779-787).

Chu, C. H., Luh, Y. P., Li, T. C., & Chen, H. (2009). Economical green product design based on simplified computer-aided product structure variation. *Computers in Industry*, *60*(7), 485-500.

Cohen, M., Regazzoni, D., & Vrubel, C. (2019). A 3d virtual sketching system using NURBS surfaces and leap motion controller. *Computer-Aided Design and Applications*, *17*(1), 167.

Corbin, J., & Strauss, A. (2014). *Basics of qualitative research: Techniques and procedures for developing grounded theory* (4th ed.). Thousand Oaks, Sage publications.

Creswell, J. W., & Guetterman, T. C. (2019). *Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research*. (6th Edition). Pearson Education International.

Creswell, J. W., & Poth, C. N. (2018). *Qualitative inquiry and research design: Choosing among the five approaches.* (4th Edition). Thousand Oaks, CA: Sage.

Daud, M. F. (2012). *Assessment of Mechanical Engineering undergraduates' Conceptual Knowledge in Three Dimensional Computer Aided Design.* (Doctoral dissertation, Universiti Teknologi Malaysia).

Daud, M. F., Taib, J. M., & Shariffudin, R. S. (2012). Assessing Mechanical Engineering Undergraduates' conceptual knowledge in three dimensional computer aided design (3D CAD). *Procedia-Social and Behavioral Sciences*, *56*, 1-11.

Dobelis, M., Branoff, T., Nulle, I., Pletenac, L., & Volkov, V. (2012). Graphics Literacy Evaluation through Interpreting Assembly Drawings: 3D Model or 2D Drawing. *publication.* 148-160.

Doutre, P. T., Morretton, E., Vo, T. H., Marin, P., Pourroy, F., Prudhomme, G., & Vignat, F. (2017). Comparison of some approaches to define a CAD model from topological optimization in design for additive manufacturing. In *Advances on Mechanics, Design Engineering and Manufacturing* (pp. 233-240). Springer, Cham.

Dukes, S. (1984). Phenomenological methodology in the human sciences. *Journal of religion and health*, *23*(3), 197-203.

Engineering Accreditation Commission (2018). Criteria for accrediting engineering programs 2018–2019. *Baltimore: Accreditation Board for Engineering and Technology (ABET) Inc*.

Gaddam, S. (1995). *Feature pair based design: defining and applying functional relationships between components in assemblies* (Doctoral dissertation, Oklahoma State University).

Grasso, D., & Burkins, M. (Eds.). (2010). *Holistic engineering education: Beyond technology*. Springer Science & Business Media.

Guidera, S. G. (2004). Assessing the use of digital sketching and conceptual design software in first-year architectural design studio. In *Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition*.

Hack, M., d'Ippolito, R., El Masri, N., Donders, S., & Tzannetakis, N. Reliability based design optimization of the fatigue behaviour of a suspension system based on external loads. In *1st Commercial Vehicle Technology Symposium (CVT 2010)* (pp. 277-286).

Hanratty, P.J. (1995). Parametric/relational solid modeling. In D.E. Lacourse (Ed.) *Handbook of solid modeling,* (pp. 8.1-8.25) New York: McGraw-Hill.

Hartman, N. W. (2005). Defining expertise in the use of constraint-based CAD tools by examining practicing professionals. *The Engineering Design Graphics Journal*, *69*(1).

Henderson, T. C. (2014). A Structural Model for Engineering Drawings. In *Analysis of Engineering Drawings and Raster Map Images* (pp. 49-61). Springer, New York, NY.

Henderson, T., & Swaminathan, L. (2003). Symbolic pruning in a structural approach to engineering drawing analysis. In *Seventh International Conference on Document Analysis and Recognition, 2003. Proceedings.* (pp. 180-184). IEEE.

Horvath, L., & Rudas, I. (2004). *Modeling and problem solving techniques for engineers*. Elsevier.

Hudson, N., Howard, T., Ma, J., Jain, A., Bajracharya, M., Myint, S., & Burdick, J. (2012). End-to-end dexterous manipulation with deliberate interactive estimation. In *2012 IEEE International Conference on Robotics and Automation* (pp. 2371-2378). IEEE.

Jost, R., Kwon, B., & Schriesheim, B. H. (2020). *U.S. Patent No. 10,755,005*. Washington, DC: U.S. Patent and Trademark Office.

Kamdar, S. D. (2015). *Design and Manufacturing of A Mecanum Sheel for the Magnetic Climbing Robot.* (Master dissertation, Embry-Riddle Aeronautical University).

Kang, N., Ren, Y., Feinberg, F., & Papalambros, P. (2019). Form+ function: Optimizing aesthetic product design via adaptive, geometrized preference elicitation. *arXiv preprint arXiv:1912.05047*.

Kasik, D. J., Buxton, W., & Ferguson, D. R. (2005). Ten CAD challenges. *IEEE Computer Graphics and Applications*, *25*(2), 81-92.

Kaufman, D. M. (2018). Teaching and learning in medical education: how theory can inform practice. *Understanding medical education: evidence, theory, and practice*, 37-69.

Kennedy, K. M. (2010). *The Essence of the Virtual School Practicum: A Phenomenological Study of Pre-service Teachers' Experiences in a Virtual School* (Doctoral dissertation, University of Florida).

Khan, A. A., Nasr, E. A., Al-Ahmari, A., & Mian, S. H. (2018). *Integrated Process and Fixture Planning: Theory and Practice*. CRC Press.

Kyoung Ro, H., Lattuca, L. R., & Alcott, B. (2017). Who goes to graduate school? Engineers' math proficiency, college experience, and self-assessment of skills. *Journal of Engineering Education*, *106*(1), 98-122.

Lee, S. G., Ma, Y. S., Thimm, G. L., & Verstraeten, J. (2008). Product lifecycle management in aviation maintenance, repair and overhaul. *Computers in industry*, *59*(2-3), 296-303.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry* (Vol. 75). Sage.

Louie, M. (2018). Modular Crates–A Holistic Design Approach for Optimizing Cube Size in Industrial Packaging. *Journal of Applied Packaging Research*, *10*(3), 4.

Ma, G., & Zhang, F. (2010). Plan Based Automated Generation of Redesign Suggestion. In *Proceedings of the World Congress on Engineering and Computer Science* (Vol. 1).

McEwan, W., & Butterfield, J. (2011). The use of process simulation methods in support of organisational learning in availability contracting. *Journal of Aerospace Operations*, *1*(1-2), 41-53.

Mehta, P. (2020). Employing eye-tracking, screen capture and artifact analysis methods to characterize re-design for Additive Manufacturing behaviors. (Master dissertation, Pennsylvania State University, United States).

Moustakas, C. (1994). *Phenomenological research methods.* London, Sage.

Nguyen, V. D., & Martin, P. (2015). Product design-process selection-process planning integration based on modeling and simulation. *The International Journal of Advanced Manufacturing Technology*, *77*(1), 187-201.

Ope-Tairu, A. B. (2016). *Effective Communication Among Construction Project Teams as a Tool for Achieving Project Success: A Case Study of Nigeria* (Master dissertation, University of Johannesburg).

Park, J., Mehrubeoglu, M., Baca J. ylance. lmoosa H. ala ar G. Falahati, S. (2019). Development of a design protocol for customized swimming goggles using 2d facial image data. In *Advances in Intelligent Systems and Computing* (Vol. 777, pp. 151–155). Springer Verlag.

Patton, M.Q. (2015). *Qualitative Research & Evaluation Methods: Integrating Theory and Practice* (4th ed.). Thousand Oaks, Sage publications.

Perzylo, A., Somani, N., Rickert, M., & Knoll, A. (2015). An ontology for CAD data and geometric constraints as a link between product models and semantic robot task descriptions. In *IEEE International Conference on Intelligent Robots and Systems* (Vol. 2015-December, pp. 4197–4203). Institute of Electrical and Electronics Engineers Inc.

Prats, M. (2007). *Shape Exploration in Product Design* (Doctoral dissertation, Open University, Milton Keynes, UK).

Pratt, M. J., & Anderson, B. D. (2000). *A Shape Modeling API for the STEP Standard*. Technical report, National Institute of Standards and Technology.

Rodríguez, M. B. (2015). *Scalable exploration of highly detailed and annotated 3D models* (Doctoral dissertation, University of Cagliari, Italy).

Silva, J., & Chang, K. H. (2002). Design parameterization for concurrent design and manufacturing of mechanical systems. *Concurrent Engineering*, *10*(1), 3-14.

Simmons, C. H., & Maguire, D. E. (2012). *Manual of engineering drawing: Technical product specification and documentation to British and International Standards*. Butterworth-Heinemann.

Smith J. A., Flowers P., Larkin M. (2009). *Interpretative Phenomenological Analysis: Theory, Method and Research.* Sage Publications, London.

Tennyson, R. D., & Breuer, K. (2002). Improving problem solving and creativity through use of complex-dynamic simulations. *Computers in Human Behavior*, *18*(6), 650-668.

Ubbes, V. A. (2008). *Educating for health: An inquiry-based approach to preK-8 pedagogy*. Human Kinetics.

Ubbes, V. A., & Njoku, B. (2022). A Curriculum, Instruction, and Assessment (CIA) Framework for Health Literacy Education (HLE) in Medical and Health Professions Schools. *World Journal of Social Science Research*, *9*(1), 15-55. SCHOLINK INC.

Vajna, S., Burchardt, C., Le Masson, P., Hatchuel, A., Weil, B., Bercsey, T., & Pilz, F. (2020). Models and Procedures of Product Development. In *Integrated Design Engineering* (pp. 1-80). Springer, Cham.

Visser, W. (2006). Designing as construction of representations: A dynamic viewpoint in cognitive design research. *Human–Computer Interaction*, *21*(1), 103-152.

Wang, J. X., Tang, M. X., Song, L. N., & Jiang, S. Q. (2009). Design and implementation of an agent-based collaborative product design system. *Computers in industry*, *60*(7), 520-535.

Yan, Z., Hongke, T., Li, G., & Guangyu, Z. (2006). Digital technology and digital product design. In *2006 7th International Conference on Computer-Aided Industrial Design and Conceptual Design* (pp. 1-5). IEEE.

Yoshimura, M. (2010). *System design optimization for product manufacturing*. Springer Science & Business Media.