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# Aesthetic Improvement: Innovating the Design and Development Framework for Engineering Products

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**ABSTRACT**

One of the primary issues with many product design and development processes today is to have a good balance between the elements of form and function. While all products must be able to perform their intended functions, considerations of aesthetic features are also necessary for them to be accepted as a good quality design. However, most available design and development processes of engineering products have been more focused on achieving the functional aspects and tend to treat the aesthetic aspects as less crucial features. This approach has led to many failed functional products in the market as their physical design lacks appealing factors to the targeted customers. To improve the situation, a new product design and development framework is proposed in this study to better facilitate designers or engineers in creating an all-rounded quality product design. This new method is developed based on the findings from a conducted survey among engineering students, who are future product design engineers, to identify and resolve issues with current methods that they use for their design tasks. All in all, the new proposed method is essentially tailored to offer a comprehensive guide for developing beautiful and useful products based on a semantics design approach.

## 1. Introduction

Today, the product market environment has gradually become more customer-driven and very competitive. The increasing demands for more customized products have also increased the complexity of product design and development process for many product companies [1]. With many options are now made available to the customers in the market for similar products, this puts a big emphasis on the quality of products to guarantee their market success. In general, a product can be taken to be of great quality if it satisfactorily meets the needs and expectations of the customers, as well as meeting other quality aspects or dimensions including features, performance and aesthetics [2]. A high-quality product must carry both aesthetic and functional properties that fulfil all requirements from customers, implying a balanced trade-off between these two major aspects of

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product design [3]. Nevertheless, making these balanced design decisions while developing the product is never an easy task for the designers or engineers, and failure to arrive to adequately good designs might jeopardize the market success of the product.

The focus of the typical product development process involving innovation management has been observed to be more inclined toward the functional values of the product, which indicates that it concerns more with the practical benefits that product's performance can offer to the customers [4]. This particular assertion has also been supported by other researchers such as Ulrich and Eppinger [5], Pandey *et al.,* [6], and Candi and Saemundsson [7], highlighted that design of engineering products is more concerned with objective functional characteristics and utility of the offerings instead of subjective characteristics such as ergonomics, look and also feel that have been more prominently considered in industrial design [7]. With such high emphasis on functional properties during the development process of engineering product designs, this situation has the potentials to lead towards market failure when the aesthetic properties of these products are not being given appropriate considerations.

In fact, product aesthetics have been acknowledged as one of the crucial factors in the marketing of a product since it greatly influences the customers' purchase intention [8]. However, it has been noted that most products that are available in the markets are usually difficult to use, unattractive and or do not exactly solve the problems that they are intended for [9]. Thus, the aim of this paper is to introduce a new design process that will enhance the quality of consumer products by emphasizing on attractiveness of the product. This framework shall help the designer engineers to give the characteristics as to connect the products with users emotionally. The novelty of this proposed framework is it being developed specifically for small design team to embedded aesthetics elements without getting professional industrial designer expertise.

Although good engineering product designs need to be balanced in terms of their form and also function, it is generally difficult to achieve this condition, especially in small manufacturing companies due to their limited resources and also lack of design skills [10]. Moreover, it is also noted that most small manufacturers typically conduct their product development process in ad hoc, unplanned, and unstructured manner, and they seldom adopt systematic design procedures [11]. On contrary, big product manufacturing firms have the capability to outsource their product development tasks to external designers, making it more crucial for the small product manufacturers to fully optimize the use of their limited resources to produce good quality product designs for their market competitiveness. Hence, it is apparent that there is need for systematic and structured approaches that can be more suitable and easier to apply in the small companies in their design process. This is identified to be an ongoing research gap that needs to be addressed.

With increasing numbers of new product introductions into the market these days, it is highly understandable that product manufacturing companies are concerned with the importance of well-designed products to their business and also market competitiveness. In response to this realization, this study intends to develop a new design methodology framework that can assist design engineers in product development process, which may essentially act as their guideline and also reference for their product design process. The potential practicality and usability of this new proposed design framework is demonstrated using an example case study of detergent bottle design for a small product company.

## 2. Literature Reviews

In essence, topics on new product development (NPD) and product design process have always garnered high interests, particularly in efforts to introduce better design procedures and quality

outputs [6]. It is common to observe in the product development process today that engineers are more focused on product's performance whereas industrial designers are more inclined toward the visual aesthetic of the product, and such separation practices between form and function frequently lead to unappealing or difficult-to-manufacture products [12]. For instance, Tao *et al.,* [13] have suggested the integration of big digital data application into the new engineering product development process that focuses on physical design manifestation of intended functions of the product [13]. Expanding upon the generic NPD management [14], the study by Amer *et al*., [15] presents an engineering-focused approach. This method advocates for integrating design for six sigma concepts into the NPD process, aiming to derive the best design solution by emphasizing performance capability [13].

Moreover, there are many engineering product development strategies that are more inclined towards design functional focus such as development of agile products and sustainable products [15]. In the meantime, new product development research in industrial design have been oppositely leaning toward a greater emphasis on the aesthetics characteristics of the product designs. Some examples to highlight this situation are observed in the study by da Luz *et al.,* [16], which stresses on the importance of aesthetics to product design, and by Hou and Lu [17], which concludes on a great influence of aesthetics on product design appeals. On the whole, it is clear that the main consideration in product design process is essentially different between the current engineers and industrial designers, even though it is acknowledged that a good quality product design requires a balanced trade-off of both functional and aesthetics aspects. The following Table 1 summarises these issues.

**Table 1**
Previous researchers with their new process developments and their limitations

| Researchers | Research work and scope | Limitations and improvements |
|---|---|---|
| Booz *et al.,* [14] | Generic NPD, seven stages of development process. Very useful for managing product management. | Cover all aspect of resources but lack of details for design team activities. |
| Ulrich and Eppinger [5] | Good technical NPD. Comprehensive framework for all types of product development. | Industrial design process not integrated, propose to hire professional for that element. |
| de Vere *et al*., [18] | Proposed product design engineering as a new interdisciplinary by combining the strengths of the industrial design and engineering. | Converging for engineering and design thinking and practices. Yet, need long-time duration. |
| Kim and Lee [19] | Simplified the collaborative processes Four types of typical collaborative product design processes and their characteristics; concept-driven process, combined outside-inside process, inside-first process and synergetic process. | To create representative process models. However, need to have a lot of experiences to use effectively. |
| Mubin *et al*., [20] | The pedagogical approach sought to determine the new industrial products reality with an increasing contribution by design thinking, and its associated methodologies that are currently advancing ID. | Design thinking-based education work in an industrial design honours program, same intent with this framework but different users. |
| Bilgili *et al*., [21] | To classify the consumer expectations by using the Kano model in the new product development and to determine to what extent the products produced in the direction of the expectations provide satisfaction. | Framework design for marketing analysis purpose and measuring customer satisfaction. |
| Kumar and Noble [22] | Study that integrates previous value typologies, this research shows that product design can create not | Only evaluate perceive aspects of self-expressive value among |

| | | |
|---|---|---|
| | only “form” and “function” related value but also a self-expressive dimension. | consumers regarding design acumen. |
| Yoshioka *et al*., [23] | Study the status and trends of smart products that are cyber physical systems with services through Internet connection. The framework identifies these emerging development technologies using model-based systems engineering and digital twin. | Highlight software-intensive, data-driven, and service-conscious, their development needs new capabilities bolstered by advanced tools, methods, and models. |

In the meantime, there are also researches by product designers in industrial design engineering that attempt to have better convergence between industrial design and engineering design in all aspects of product design and development process including those by de Vere *et al.,* [18], Kim and Lee [19], and Mubin *et al.,* [20]. Additionally, there are also various research and also case studies of the product design process that have been focused on the specific contexts and methods. For instances, the Kano and Nagamachi methods have already been improvised and or adapted multiple times for application in new domain functions in numerous studies such as Bilgili *et al.,* [21], Kumar and Noble [22], Yoshioka *et al.,* [23], and Low *et al.,* [24].

Nonetheless, there have been some research efforts to close existing gaps between industrial and engineering product designs. Kim and Lee [19] outlined the possible collaborative design effort between engineers and industrial designers in product design process. On the other hand, Mubin *et al.,* [20] researched on the inclusion of the functionality and fidelity, user and society value consideration by the industrial designers instead of just the common beauty and form factors. In addition, Schneller [25] explained the bridging concept between the product form and function while Kang [26] has infused aesthetics consideration into engineering product design development process. Despite these research efforts, however, the separation issue between form and function considerations in the new product design process appears to largely remain at this moment. This situation has been highlighted in several studies including Muminovic *et al.,* [27], Adair [28], and Yu *et al.,* [29]. Therefore, there is indeed an ongoing need for the better product design framework that can effectively bridge this identified gap, which is in line with the recognition that aesthetic features are progressively essential in guaranteeing market success of modern engineering products these days [30].

In general, the need for the capability to produce good quality product designs is understandably more urgent for small product companies due to today’s high level of market competition. It is also noted that these small and medium enterprises (SMEs) are an important part for sustaining a good economic health in both high and low-income economies worldwide [31]. In contrast to their big corporation counterparts, SMEs often operate within a limited funding and human workforce, which increases their significance in having the capability to produce good quality products with an optimum use of their resource. By the notion that these SMEs have to be focused on more to assist their market survivability, there have been numerous studies that propose design frameworks to facilitate the designers and engineers for the new product development process in the small manufacturing companies’ settings.

Dutta *et al.,* [32] studied the potential of the digital transformation while Chen and Liu [33] explored a systematic participation of customers in green product designs for SMEs. Other example studies on this particular matter include Gherardini *et al.,* [12], Cederfeldt and Elgh [34], and also research team Lovett *et al.,* [35]. On the whole, while most of these frameworks capture the essences of systematic engineering product design and development process, the one that can guide the focus on balancing functional and aesthetic properties of the new product design is found to be still lacking.

This is especially true for such design frameworks that can be suitably applied in the limited operational settings of the typical SMEs.

### *2.1 New Product Design Framework Development*

The design framework models can generally be classified based on two primary factors: the criteria of the target scenario and the overall purpose of the model. Additionally, as depicted in Figure 1, the organizational structure of the design framework can be broken down into four major categories: abstract, management science and operations research (MS/OR), procedural, and analytical models. Abstract models articulate hypotheses and theoretical insights regarding the design and development process (DDP). These models provide valuable insights into the DDP and aid in the creation of practical approaches. However, many of these models do not offer specific guidance to practitioners. On the other hand, MS/OR models encompass a broad perspective on DDP concerns, involving statistical or computer analysis of representative or synthetic cases. These models lay out guiding principles for managing real-world scenarios, particularly in the case of procedural models. Lastly, analytical models provide situation-specific insights, improvements, and assistance by reflecting on the unique circumstances of the DDP.


**Fig. 1.** Positioning key models of design and development within the framework [36]

Within the context of the framework flow, the DDP presents particular challenges in terms of handling and monitoring. Researchers have developed a variety of process models to comprehend, enhance, and support the DDP, considering its distinctive attributes. However, it's important to note that no single framework can address all of the associated issues. In fact, many of the models that have been created exhibit diversity in their focus and formulation. It is suggested that process frameworks are typically tailored to specific objectives, and they can be organized into similar models where each model within a given cluster may have interconnecting modules. The level of simplification or abstraction applied to the representation of a concept or envisioned scenario within the model is greatly shaped by the intentions of the individuals or team responsible for the modelling [30-32].

Meanwhile, in order to appropriately embed the aesthetic elements into the product design, some of the strategies by Krippendorff [37] can be considered. In his work, due to the realization that the support for the systematic concerns of the semantic aspects in product design is somewhat inadequate, it is suggested that some practical creative human-centred methods or strategies can be applied to correlate back the product designs to the semantic framework that defines their meaning or connotation. The first strategy is to design or redesign according to envisioned character of the product to be developed, which can be taken as the most crucial step to infuse aesthetic elements into the product design. The other strategies include designing informative or expressive products, planning for the design strategies to achieve balanced form and function characteristics, designing original products that are driven by the narratives and metaphors, and establishing dialogical ways to design the product.

## 3. Methods

The work in this study is accomplished using research approach that can be essentially divided into four main stages. The first stage involves study and analysing current design framework and their limitations. Then from previous research also the knowhow is used to draft a new framework. Then conducting a survey to gain better understanding on reasons why a separation between form and function approaches is still greatly happening in product development process and how to effectively close this gap. Based on the findings from the field investigation input, full effort be given to the development of the new proposed design framework to aid in improving this situation. The semantic turn approach has been chosen to be the suitable method for developing this proposed framework. All in all, the literature review has coverage regarding stage one, more details on the two major stages of the research discussed in following sections. The following Figure 2 aptly summarizes the main steps in this study.

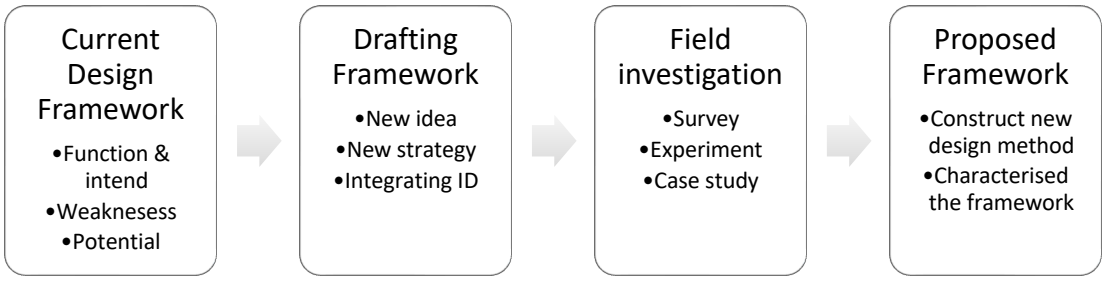


**Fig. 2.** Summarized research methodology

Since the situation is found to be more pressing for the small product manufacturers, the proposed framework in this study is mainly tailored for application by small design group in micro-

enterprises and new apprentices within the local contexts of SMEs in Malaysia and for teaching future product engineers in the undergraduate engineering programs of local universities. The latter is also taken into the consideration as it has been noted from the findings of previous conducted survey study that most local product designers are indeed aware of the importance of aesthetic product elements but most of them unfortunately do not typically incorporate the considerations into their product design process [38].

This is hardly surprising as this situation is principally similar to the common ongoing issues with the general product development worldwide. For this reason, it is believed that having a structured guideline to support them can positively improve the execution of product design process and the quality of their design outputs. The new proposed process framework in this study is envisioned as a guide or reference for design engineers in the product design and development process, which aptly adapts some of structured qualitative approaches that assist in maintaining their design focus throughout the process [39].

### *3.1 Drafting the New Framework*

Taking prior established strategies and design process models as Wynn and Clarkson [36], Hanid *et al.,* [40], and Romli *et al.,* [41] as comparative references, a new design process framework that can promote the proper inclusion of aesthetics consideration into the product design is developed and proposed. This framework is also incorporated with underlying principles for idea generation in product design process and this element effectively differentiates it from other existing product design and development process frameworks. The development of proposed framework in this study is primarily aimed to facilitate a smooth integration of the local industry expectations into the curriculum of related undergraduate programs in the form of design methods and tools. All in all, Figure 3 portrays the cross-functional flowchart as draft with the associated design processes and activities for each stage of the proposed product design and development framework.

As mentioned before, it is believed that a good fundamental knowledge during their study will have great effects on the approach that the product engineers are inclined to apply in product development process once they have graduated and employed in the industrial workforce. Hence the proposed framework must be both easily implemented within the industrial settings of small product companies and also as part of the lesson inside design courses of the undergraduate engineering program. The foundation of this proposed design framework is semantic turn paradigm, which suggests the distinction between technical and user-related operating aspects of artefacts [42].

In essence, the beginning of the product design process can be triggered by several factors such as the client's request, new start of product refreshment design cycle or new product idea. The right interpretation of the customers' needs and preferences for the product design is very crucial to the success of the product development, and this has been highlighted in the numerous product design research including Veryzer and Mozota [43] as well as Wang [44]. Regarding this particular framework, the current emphasis lies in the infusion or integration of aesthetic elements through various industrial design (ID) tools and techniques.

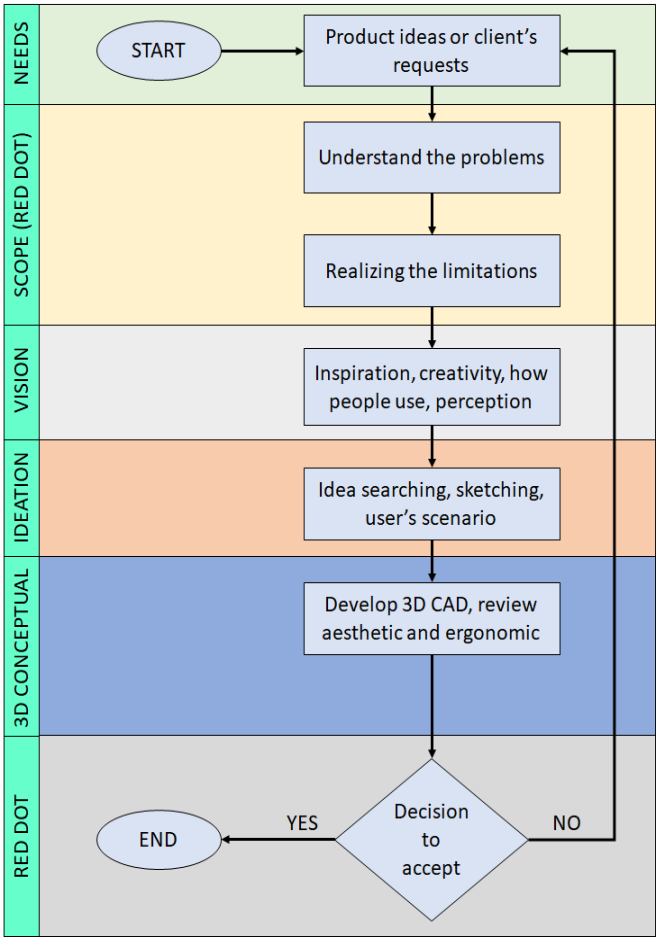


**Fig. 3.** Suggested activities in product design process for the new proposed framework

Starting from the design brief, the process involves incorporating industrial design elements by employing a dual set of descriptive adjectives, known as bipolar semantics, to articulate the characters of idea. Subsequently, web browsers leverage artificial intelligence (AI) technology to visualise these images, enabling designers to consolidate their creative visions into a cohesive mood board. In view of this notion, human interaction with the artefacts, either individually, socially or culturally, should be treated as an essential criterion during the design process. This includes addressing the design elements that ordinary users may not fully understand and use of technologies that most users may not care about. By having a good understanding of the users and stakeholders through ethnographic research and making the design decision according to that understanding, it is possible to better design the characters of artefacts where the correctly established semantics will provide the artefact with its desired characteristics [45]. For the following stage, the design team can represent and visualize the compiled ideas into the sketching of the product designs. It is typical to have several design alternatives at this stage and the best idea or concept is then chosen through proper design evaluation method. In other words, a few different sketches of the product design are systematically assessed and the best among them is chosen to be carried on to the next stage of the process. Another design validation process will then be conducted after improvements have been made to the product design.

In this particular study, it is believed that a structured qualitative design method will lead to the construction of a new form of NPD that is able to guide designers in balancing between the form and function elements of their product design. Development of this proposed design process framework

aptly takes into account all personal experiences and viewpoints of the industrial supervisors who have been previously involved in the industrial training sessions for the local undergraduate engineering programs. One of the primary goals of this new design process framework development is to be a means for the creative process where aesthetic features are aptly structured into the design process, such that even a non-creative person can also consistently come up with good quality product designs that achieve the desired expectations.

In addition, the proposed design framework should make use of existing off-the-shelf tools and technologies, which will help ease the design process for simple products and also make it easier to be accepted by all. Therefore, as part of the framework development, it also includes the search and selection of suitable design methods and tools for major steps that can ensure the effectiveness of this framework in facilitating product designers in their design decision-making process. Figure 4 illustrates the tools employed to generate a final result that possesses a sense of 'soul' and aesthetic appeal. These tools have been thoughtfully and selectively curated, as they have been proven to enable designers with an engineering background to delve into the essence of product aesthetics.

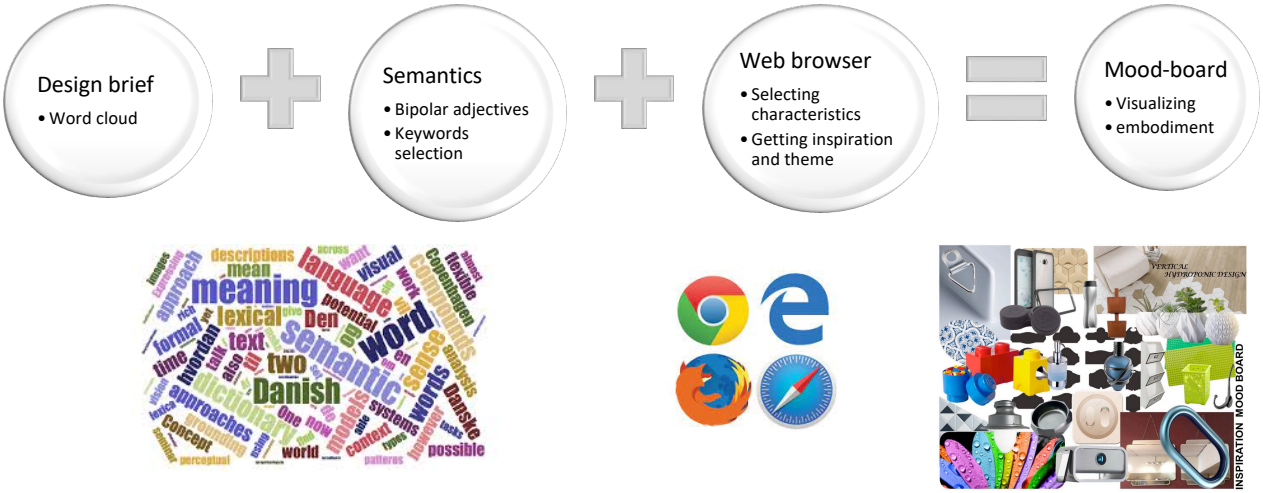


**Fig. 4.** Aesthetics elements infused using ID tools in the framework

The final assessment is made once the full-scale product is fully designed and developed using the process framework, which attempts to better assist design engineers in observing and verifying the product throughout the process, with substantial effort in infusing the aesthetic elements during the product creation. In the succeeding stage, the product design is constructed into a three-dimensional (3D) computer-aided design (CAD) model. The 3D part is rendered in 3D CAD software, and this enables the product design team to conduct a comprehensive design review and effectively proposes the selected product design idea and concept to both the marketing and manufacturing teams. If the design proposal does not receive the full agreement from these two teams, the product design team is required to iterate the process cycle until the best alternative is found. Only after the product design proposal has been approved and accepted by all, it will move into engineering design phase where its detailed design is developed for the manufacturing process.

### *3.2 Field Investigation*

Conducting a survey is a common method that can be applied to gather or collect data from the pool of target respondents with regard to the interested topic or issue. From a public survey to analyse the market needs to a survey to gauge the importance of certain particular issues on the grounds. In general, conducting a survey is an ideal way for documenting perceptions, attitudes,

beliefs and knowledge among a clear, pre-determined sample of individuals [46-48]. This matches with the aim of the data collection in this study, which is to establish the underlying deficiencies of the current practices in the product development process among local product engineers. Most engineers often directly adopt design methods that they have learned during their study into their working career. Along with this notion, it can be justified that they can be represented by the graduating senior engineering students in the pool of target survey respondents.

The survey instrument for this study has been tailored to this objective and it can be divided into two major sections. In short, the first section is designed to assess the respondents' capability to recognize the product's functional and aesthetic elements using visual stimuli of two different water faucet designs. In the meantime, the second section is tailored to verify the knowledge of the respondents with regards to aesthetic theory and design process of components or products, as well as consideration of aesthetic elements in their common design practice. Their gathered responses are analysed and summarized to draw appropriate conclusion on the separation between the form and function approaches in common product development process today. It should be noted that the survey has been conducted on voluntary basis in a face-to-face manner. Overall, a total of 166 responses are collected. The volunteers are senior undergraduate engineering students from three local public universities in Malaysia: Universiti Putra Malaysia, Universiti Tun Hussein Onn Malaysia and Universiti Teknikal Malaysia Melaka.

In second part of field investigation, a pilot validation experiment case study using the drafted proposed new design framework is conducted with the volunteering undergraduate students. A sample application case study is commonly used. Romli *et al.,* [41], and Zhang *et al.,* [49] for example successfully demonstrated this approach to support their framework design. It is to demonstrate the implementation feasibility and practicality of a new proposed design framework.

In this study, the students are paired together into product design teams. The given task is to propose the design of a detergent bottle for a real-life industrial company. At the first stage, the team is instructed to produce the bottle design based on their previously learned generic design process. Although the design process has been properly executed by them according to their learned knowledge or experience. In the second stage of the experiment, the design team is trained to apply the new design framework in their design process for their second design.

## 4. Results

### *4.1 Survey Findings*

Before a new design process framework is developed, it is good to establish the deficiencies and issues with the current practices by most of the product designers. This knowledge will be good basis and foundation for the framework development. In this study, a survey is conducted among undergraduate engineering students in three local public universities in Malaysia, who are potential future design engineers within local product industry. All in all, 166 volunteers have participated in the survey. Among them, about 57% of them are males while the rest are females. Their age range is between 21 to 25 years old and since they are still undergoing undergraduate study in engineering programs, they all have closely similar level of design experiences and are exposed to reasonably similar design theories and knowledge. Overall, it is taken that this pool of survey respondents can effectively represent current situation with most of local product design engineers according to their learned design knowledge that will be applied in their working career later on after graduation.

Based on the gathered responses, all respondents have admitted that they have already done tasks or activities regarding the design of products or components during their duration of study, and they have also been taught about design methodologies and tools. Moreover, they are well aware

and acknowledge that aesthetic features are indeed an important factor in design of consumer products. This is a good indication that the respondents have the necessary background to accurately respond to the questions in the survey instrument. On the other hand, when queried on whether they think they have been given enough exposure on the matter of aesthetic design theory and knowledge, only 34% of them said yes. The other 66% of the survey respondents believed that they could have learned more during their study to allow them to apply the theory and knowledge more effectively. This situation is also further reflected in the respondents' feedback on whether they applied any specific method to embed the aesthetic elements when they carried out their design tasks or projects, to which 75% of them said no. However, the majority of survey respondents, or roughly 80% of them, do believe that implementation of aesthetic elements into the product design will definitely increase its value. In fact, 81% of them respondents are very confident that the selling price of good quality product designs with exceptional aesthetic elements can be comparatively much higher than those without, which subsequently increases the profit margin for the product company. Overall, this finding clearly supports the notion that, although many product design engineers have been fully aware and acknowledge the high importance of design aesthetics to market success of the products, not many of them actually implement it during the design process due to more focus is probably placed on the functionality of the product design or simply because they lack proper skills to do it because they are not effectively trained to do so.

To further assess the level of understanding among the survey respondents with regards to definition of design aesthetics, they are asked to give few common words that are highly representative to the meaning of design aesthetics to them. Table 2 tabulates the five top words that have been selected by the respondents in respond to this query, with "colour" leading the list as chosen by the respondents. The other words that are associated to product design aesthetics include material, ergonomic, functionality and reliability. Based on these answers, it can be concluded that the surveyed engineering students did not fully understand the proper definition of design aesthetics. The students have gotten the word "colour" right as it is indeed one of the well-known elements for product aesthetics. As for "material", the perception is rather divided. While it is correct that material for the product design can be selected to make the final outlook or finishing of the product become more attractive, the selection can also be considered as part of the functional aspects for the product design to ensure it can effectively function as intended under its operating conditions.

**Table 2**
Representative words for product aesthetics

| Word Choice | % Respondent |
|---|---|
| Colour | 97.0 |
| Material | 69.5 |
| Ergonomic | 68.8 |
| Functionality | 67.0 |
| Reliability | 50.9 |

On contrary, remaining three chosen words by most of the respondents clearly show that they have the wrong perception with regards to design aesthetics. The word "ergonomic" is related to the human interactions with the product, which is seen as more functional in nature instead of aesthetics. The word "ergonomic" is hardly used to describe beauty and attractiveness of a product design that are truly associated to aesthetics concept. Moreover, the engineering students definitely missed the point with the chosen words of "functionality" and "reliability". It is evidently clear that these two words are heavily related to the technical aspects of product design and they are not representative

of aesthetics at all. The fact that a high percentage of the respondents choosing them is a worrying situation. “Functionality” is often referred to the ability of the product to operate as intended whereas “reliability” is closely associated with the dependability level of the product design to perform its function consistently well.

On the whole, it is concluded from the findings of the conducted survey that all respondents do acknowledge the essence of aesthetics in the product design that can increase its value. However, it appears that most of the engineering students are not appropriately introduced to the essential theories and knowledge of aesthetics, thus have some misunderstandings regarding product aesthetics. Based on this realization, it is believed that having a guiding design process framework will be of a great help for these new product design engineers in producing good quality products. In view of this, the adaptation of design approach that involves the use of concepts of categories, characters and identities within the semantic context seems to be a good assistance for product design engineers to infuse aesthetic elements during their design process [27]. This proposed new process framework is expected to fill the identified gap in the implementation of product design aesthetics and facilitates novice product design engineers to gain the appropriate product design skills.

### *4.2 Validation Study*

A pilot validation experiment case study employed to show the implementation feasibility and applicability of a new suggested design framework. To begin, an experiment case study employing the suggested novel design framework is carried out with the help of volunteer undergraduate students. Even though they carried out the design process correctly based on their learned knowledge or experience, the resultant detergent bottle design, as shown in Table 3, is found to be rather common and lacking in character that could be associated with the characteristics of the actual product. In other words, their output detergent bottle design is not adequately indicative of the product, brand, and emotion, and it lacks vital feeling that potential buyers may relate to. It is evident that the resulting second bottle design is far superior in terms of aesthetic aspects. The same design team was able to link the bottle's character to the detergent's pear sweet scent. Furthermore, the container design appears to aim to emotionally connect with the product's scent, visual, and form senses.

**Table 3**
Results from the conducted preliminary experiment study

| Before | After | After (group 2) |
|---|---|---|
|  |  |  |
| • Properly designed.<br>• Theme not clear<br>• Characteristics cannot relate to the product and branding.<br>• No emotion attached. | • Design inspired from the detergent characteristics.<br>• Pear fruity smell becomes main design focus.<br>• The design attempts to connect smell, visual and form senses of product emotionally.  | • Design inspired from aquatics.<br>• To give impression environmentally friendly detergent.<br>• Will not harm aquatic plants.  |

As additional controlled experiment evident, another group of students had been asked design another detergent bottle using this newly established design framework. As in Table 3, they managed to create emotional link by aquatica inspiration. They are able to give impression that this detergent is friendly to aquatic plants, not harmful to the environment. It reflected in bottle design. All in all, based on the results from this experiment, it can be taken that the new proposed design process framework has shown its potential and also ability to successfully guide and assist designers to embed better aesthetics value into their product.

### *4.3 Refinement of New Product Design Framework*

At this stage, all findings from survey and controlled experiment be considered as input to give this framework its final diagram. As also has been established in the prior studies on product design process, three main parties involved in the inquiry of stakeholders' concepts and motivation for the product design and development are the marketing, design and manufacturing teams. Each of these parties clearly has their own expertise and specialties, which makes their involved participation and contribution in shaping up the narrative or description for the ideal product design is crucial. This creates the triangulation of approaches that should seriously be taken into account during the product design process. Additionally, to better reflect or highlight the iterative nature of the product design process, the circular type of process framework that is being proposed in the Delft design method is adopted for the new framework instead of using typical linear or sequential process [48].

Once the agreement between these three teams has been reached and accepted by all parties, the product design team can effectively begin the design process. In the vision stage, the design team needs to visualize the implementation of product innovations into the design. Among others, the team can generate some inspirations or ideas for the product design using several visual simulations such as videos, photos and physical objects. The design team should also consider applying the user's empathy approach on the product, along with the intended functions and ergonomics of the product design.

For the following stage, the design team can represent and visualize the compiled ideas into the sketching of the product designs. It is typical to have several design alternatives at this stage and the best idea or concept is then chosen through proper design evaluation method. In other words, a few

different sketches of the product design are systematically assessed and the best among them is chosen to be carried on to the next stage of the process. Another design validation process will then be conducted after improvements have been made to the product design. The final assessment is made once the full-scale product is fully designed and developed using the process framework, which attempts to better assist design engineers in observing and verifying the product throughout the process, with substantial effort in infusing the aesthetic elements during the product creation.

In the meantime, through the use of CAD, computer-aided manufacturing (CAM) and also computer-aided engineering (CAE) technology, engineering aspects of the product design can be properly analysed upfront as well. The current advancement of CAD, CAM or CAE can be fully utilized to ensure a smooth transition from the design and development phase to manufacturing phase. Furthermore, there are many instances where certain product designs are judged and evaluated in the early phases of the development process. With the aid of the virtual reality (VR) technology, the marketing, design and manufacturing teams can efficiently assess the product designs and reach an agreement during the early stages, which will contribute toward higher rate of success for the product to be developed. Only after the product design proposal has been approved and accepted by all, it will move into engineering design phase where its detailed design is developed for the manufacturing process.

Once all activities involved in each stage of the design and development process have been identified and also defined, the overall framework can be reconstructed. As suggested by Krippendorff [37], the attribute meaning and also the methodology for designing the product should be clearly recognized. Therefore, the key principle for the proposed process framework is tasks separation between product design and product development. This is appropriately reflected in Figure 5, which illustrates the structure of the proposed new design framework and indicates how the concerns of the tri-parties' involvement in the product design and development process are handled. The red dot inside the framework is effectively the decision point for all three different teams involved and it also technically signifies the starting and ending point for the process framework.


**Fig. 5.** Proposed new process framework for NPD: Infinitive Qualitative Method (IQM) for design

At this particular point of the framework, the outcome proposal from the product design team will be discussed and evaluated. The marketing team will concurrently conduct the survey on the product to be developed along with the conceptual design progress while the engineering team studies the limitations in relation to the production of the product. In essence, by having separate processes for product design and product development, it allows the product designers to stay more focused on the designing tasks as the NPD progresses. This situation is practically preferred as it significantly offers more opportunities for the product design team to fully explore the design space and thus produce better product design proposals that have high potential.

Depending on the outcomes of the conducted reviews and discussions, design iterations for the product are expected, which can be of major or minor magnitude. Major design changes often require the product design to go back to the fresh start of the conceptual design process while minor design changes often only involve some small revisions of the 3D product model. The proposed product design and development framework also considers that the developed product may require some "facelift" design revisions within a certain period of time after it has entered the market. This is to ensure that the product is able to remain "fresh" according to the customers' expectation and be competitive against its market competitors. Based on this notion, overall product design and development process covered by the proposed framework is infinitely iterative in nature and this is reflected by the given name for the proposed new design framework: Infinitive qualitative method (IQM) for design.

## 5. Discussion

From the conducted survey, it can be inferred that most engineering students do not fully understand aesthetics in product design. Although they do acknowledge the importance and the essence of product aesthetics, they are more inclined to concentrate on the functional side of the product design due to the high emphasis on such practice in their learning design courses. This is in line with the hypothesis that many engineers tend to focus more on the functional capability of the product design instead of its aesthetic features. Subsequently, due to their inadequate exposure to theories and knowledge of design aesthetics, their resultant product designs are often lacking the necessary appeal to the customers or users. Realizing the need to support these future engineers in producing good quality product designs, which should be balanced in terms of both their form and functions, the new IQM design framework has been proposed.

Through pilot experiment, it can be very positive outcomes when the engineering students be able to give the detergent bottles distinction characteristic as well as improve the quality of the product. As four stages adapted in this research, it confirmed that there are needs in improving for quality and aesthetics from analysis of the survey. Then to begin with, semantic approach is used as tools to find suitable characters for the product. The semantics tool will give designers to think and adopt a correct keyword as inspired the design, from the survey, they indicate inability to determine their product quality, with semantics turn paradigm tools its resolved. As in this experiment, designers select a pear and aquatic plant as inspiration theme. As for construction of new product design development process framework, it begins with generic process flow chart, then adding input from survey and experiment, a final framework as Figure 5 can be established.

It is believed that this proposed framework is easy to be implemented and appropriately suited for small design teams as often encountered in SMEs. Furthermore, the framework should be able to facilitate novice product engineers in developing good quality product designs with the proper consideration of design aesthetics. The applicability and potential improved design outputs by using the proposed IQM framework have been shown through the short experiment study whereby the

design produced after the participants have learned to use the framework is demonstrated to be better in comparison to the one that they produced before the introduction.

### *5.1 Limitation*

It should be noted that the proposed IQM framework is tailored to the design and development of consumer products where the aesthetic features play a great role in their market appeal and success. The integration of aesthetics consideration into the main product design process is the primary essence that sets this proposed IQM framework apart from the other available design frameworks and methods. Therefore, with this notion, the IQM framework is not directly applicable or even suitable in the designing process of products that have little aesthetics importance such as heavy machinery.

## 6. Conclusion and Future Work

According to the data and findings from the conducted study, it is indicated that most engineering students (or potential future product engineers) have not been fully exposed to aesthetic elements of consumer products. This is despite the fact that design aesthetics have been established one of the important factors for successful product designs. As demonstrated from the collected responses of the conducted survey, though most of the respondents have been able to identify and recognize the aesthetic elements in the product design, they have difficulties in figuring out how to properly integrate such features into their product design. In order to ease this situation, a new product design framework called IQM has been developed based on the semantic turn paradigm. This new process framework is tailored to guide the engineering students or product engineers in a structured and objective approach to better balance the aspects of functionality and aesthetics during their product design development process. It is anticipated that, by following the proposed framework, the quality of product design will be improved. The effectiveness of this proposed framework in producing great product designs has been initially demonstrated in a simple and short experiment of a detergent bottle design. In order to better highlight its potentials and also effectiveness, a more detailed case study on its implementation and also application will be conducted in the near future.

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