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How Companies adopt different Design approaches

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Abstract: Product design process cannot be explained without both industrial design and engineering design. However, the two fields have different design approaches toward product design. This study explored different types of combined design approaches that companies adopt with industrial design and engineering design. Industrial designers and engineering designers from six global consumer product companies were interviewed. As a result, three different types of combined design approaches; Industrial design-led design process, engineering design-led design process, and cooperative design process were identified. The companies adopted the processes differently based on their purpose and situations. In particular, Industrial design-led design process cases were strongly implemented by the CEOs' strong support who believed industrial design is the primary route to secure competitiveness of their products. However, engineering design-led process was mainly used for redesign of existing products. In cooperative design process, both design groups work collaboratively in concept design phase.

Keywords: corporate design process, industrial design, engineering design, product design

1. Introduction

Companies have long taken integrated approaches to design to achieve innovation, while the academic world has researched and educated on industrial design and engineering design as two separate disciplines from a dichotomous view. Products known to be successful and well-designed are not only well-engineered and functioning, but also attractive and easy to use. This implies that well-designed products are achieved by the integrated contribution of engineering and industrial design (Cross, 2008). In the consumer product domain especially, these two design fields are essential to bring successful products in market. As such, product design could hardly be explained without an integrated viewpoint of the two fields.

While developing a product, indeed, industrial designers and engineering designers deal with the exterior and interior of a product collaboratively in industry. This leads to different

roles and approaches in design process between industrial and engineering designers causing conflicts between the two groups (Cross, 2008; Hubka & Eder, 2012). It is known that engineering design and industrial design have considerably different aspects (Pei, 2009; Persson & Wickman, 2004), and their design strategies are opposite to each other (Eder, 2013; Hosnedl, Srp, & Dvorak, 2008; Pahl, Wallace, & Blessing, 2007). Industrial designers mainly focus product-using functionality, whereas engineering designers emphasize product-working functionality (Kim & Lee, 2010). The industrial designers' role includes enhancing user experience of a product and developing its outside form and interface (Ulrich & Eppinger, 2012). They employ knowledge and skills in aesthetics and ergonomics (Eder, 2012; Pahl et al., 2007). Their role has been expanded since industrial design activity is considered value-driven. They create culture, experience, and meaning for creation (Press & Cooper, 2003). Under the interaction with industrial designers, engineering designers take part in implementing the design concept developed by industrial designers (Sara Persson & Warell, 2003). They provide a means for the product to be functioning, reliable, and manufactured (Hubka & Eder, 2012; Pahl et al., 2007). In the engineering design field, however, industrial design has been traditionally considered as an afterthought. Major engineering literature (e.g. (Hubka & Eder, 2012; Pahl et al., 2007)) has a stance that industrial design is classified as an art-oriented design that considers the aspects of product appearance, such as styling, form, and colour that are set after the technical features of products are determined.

When these two different types of designers work together with different approaches, how does the whole design process proceed? To answer this, (Kim & Lee, 2010) suggest two different types of design approaches in integrated mode of design process; inside-out and outside-in approaches. Inside-out approach is one that engineering designers define product-working functionality first following which industrial designers complete product-using functionality, while in outside-in approach, industrial designers define product-using functionality first and then product-working functionality is determined by engineering designers later (Kim & Lee, 2010). Although, these two design approaches are collaborative and close interaction takes place between the two designer groups, however, industrial designers and engineering designers have mainly negative perceived images of each other (Kim & Lee, 2014a). This seems to be caused by intransigence and lack of knowledge between the two groups (Kim & Lee, 2014b). Nevertheless, the two groups are the major parts in product development, especially for innovative product design. Companies may strategically adopt one of the two or another approach for their own purpose and situations. Sometimes, a company may use an inside-out approach to develop a technologically durable product or, an outside-in approach to attract high sensitive young users. Or they may have other significant rationales to apply a certain approach. Thus, it is needed to understand two groups' collaborative design approaches empirically. Therefore, this research focuses on what design processes or approaches do global consumer product companies take and, how do they employ them? With these questions, the author investigated how and why companies adopt different design approaches with industrial design and engineering design. Even though, a company employs industrial design and engineering design in an integrated

effort, it is hypothesized that it uses industrial design-led (or outside-in) design process or engineering design-led (or inside-out) design process for certain purpose or context.

2. Research method

The author visited six Korean consumer product companies and interviewed in-depth with three industrial designers and two or three engineering designers from each company. In sum, 18 industrial designers and 16 engineering designers were interviewed. The companies were coded as A, B, C, D, E, and F for the study following the visiting order. Company A and F were home appliances manufacturers. Company C and D were mobile communication device manufactures. Company B produced IT products and Company E was a security device manufacturer. They were prominent in their business areas and famous for well-designed products, notably in South Korea and some of them across many countries. Moreover, the companies remained Good Design awardees for several years. In terms of organizational structure, they had independent product planning, industrial design, engineering design, production, finance and marketing teams that are central to product development in a company. The number of industrial designers was approx. 5 to 10 in company B, E, and F, 10 to 20 in company A, 40-50 in company C, and around 100 in company D. The number of engineering designers among them was more than twice of the industrial designers. Generally, the role of product planning team was to plan new product development and make an annual roadmap of product development based on market research. Thus, industrial design and engineering teams worked closely with product planning team. Apart from company B and F, all companies had separate product planning and marketing teams. The product planning teams in company B and F were responsible for both products planning and marketing, however the other companies had independent marketing teams (both domestic and overseas marketing teams) as well as product planning team.

During the interview, design processes that each respondent experienced were asked and audio-recorded. The interview time was about 70 to 100 minutes. The collected interviewed data were transcribed and analysed to identify how integrated design processes of each company proceeded. Although, the transcribed data contained huge and rich information about design activities, events, process, etc. The main analysing point for this study was to ascertain whether industrial design led the overall design process or engineering design. It was proceeded by determining whose tasks were preceded and influential. That is, if industrial designer's tasks forewent and their outcomes constrained engineering designers' jobs, it was determined as an industrial design-led design process, whereas, if engineering designers started the work before industrial designers and the result of engineering design restricted industrial design works, it was determined as an engineering design-led design process. A few cases were not categorized into the two cases and rather showed combined effort of both designer groups at the initial stage. Thus, they were grouped into cooperative process. Along with this analysis, the context and background of the processes were analysed.

3. Design approaches

It was cleared that companies used different design approaches with industrial design and engineering design. Company A, C, and E employed both industrial design-led and engineering design-led design processes for particular purposes. Interestingly, Company B used only industrial design-led design process, where industrial designers' roles were much emphasized, and Company F used only engineering design-led process. Cooperative process were found in two cases; Company A and D. The purpose and context that the companies used particular processes were followed.

3.1 Industrial design-led design process

The Case of Company A

Company A applied this process for the first time in 2006 to use its competence at industrial design for developing innovative products including those of new categories that could lead to a new market. The process was institutionalized following the industrial design team's proposal to the CEO. As per the process, the industrial design team carries out an annual concept design proposal event for future products, selects a superior design developed here, and decides on commercialization. At the time of the interview in 2011, a total of 3 products were reported to have been developed via the process.

The company's process is characterized by its industrial design team developing design concepts of products independently without any external interference through the proposal event. The design concepts selected in the proposal event are used for reverse product planning, where the product planning team finds a target market for the design concept. This is totally different from the well-known process from the textbook, where the target market is identified based on market research, and products are planned and developed for the market.

In a reported case of product development, they had to make the interior parts, and accordingly the exterior form, bigger in order to implement desired performance in the second phase, where engineering designers decided on the product's functionality and reviewed its feasibility. Industrial designers decided such modification of the form would destroy the overall style concept and slightly scaled up the exterior form from the initial design to maintain the morphological concept.

In this process, industrial designers' roles are most important. Products are planned and developed in line with the concept of usability and the exterior form defined by industrial designers. Clearly, industrial designers are exclusively in charge of the overall concept development guiding the direction of product implementation, while engineering designers implement the concept developed by industrial designers through technical solutions. Even though this phase may be regarded as another concept design phase (i.e. engineering concept design phase) in light of the existing concept of engineering design, industrial designers play dominant roles in deciding on product concepts in the entire process as they

set up the direction of product development in the initial stage, whereas engineering designers are to devise interior working function principles matching the concept and exterior form decided by industrial design and ultimately to ensure the operability. This is quite inconsistent with the existing engineering design process (e.g. (Dym, 1994; Haik & Shahin, 2010; Pahl et al., 2007)), where engineering designers are assumed to play extensive roles in concept design. Then, what made this process emerge? Basically, the CEO's strong design-oriented policy seems to have exerted significant influence. Interviewees mentioned that the CEO adhered to a strong design-oriented management and considered industrial design an important tool for developing innovative new products.

> An industrial designer: "We can clearly say that designers take the initiative. Most of all, the design division is under immediate control of the CEO. Once we gave design data to the engineering team, where they arbitrarily changed the design for mass production. The CEO said, 'Give me the mock-up,' and found it totally different. Then, we dumped all moulds and made it from scratch. Afterwards, the design division has come to exercise powerful influence."
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> An industrial designer: "The CEO said, 'From now on, when you designers decide to apply a certain material, you find a supplier or other entities capable of making it happen proactively before it is too late. Relying on the lab is likely to end up in low surface quality.' So we have tried hard to proceed with CMF (colour, material, finish)."

In this company, the industrial design division shares a building with the CEO, while the engineering design division is located in a different place within a 30 minute drive, which indicates industrial design undertakes overarching roles and functions.

Most interestingly, this company relies exclusively on industrial design's creativity for product development without product planning, which is completely opposed to the conventional belief that product development starts by identifying market needs via scientific and systematic market research and analysis.

This implies that new products are developed not by market needs or technological innovation but by certain pictures designers draw in their minds.

The Case of Company B

Unlike others, Company B was only using the industrial design-led design process to develop both modified versions of existing product designs as well as new products. As industrial designers decide on the initial interior layout of parts as well as the exterior form, they undertake the role of engineering designers to some extent. As engineering designers hardly engage in the process, the industrial designers' intention is definitely reflected in the initial design development. As a result, the industrial designers become influential and take the initiative in decision making, whereas engineering designers' roles are reduced.

Firstly, the product planning department decides on a product specification. The industrial design team receives the 3D CAD data about the parts matching the specification from the product planning team or engineering design team, and lay out the parts while deciding on

the exterior form. Thus, they have knowledge about how to lay out the parts and how the layout affects the form.

The engineering designers wait for the industrial designers to decide on the exterior form. Upon receipt of the 3D CAD data, they check the interior layout of parts and feasibility. From this moment, the engineering designers fully engage in the design process.

Although, the industrial designers decide on the interior layout considering the exterior form, problems remain if the gaps between the interior and exterior parts are too narrow to produce. Therefore, the product's interior and exterior are modified and developed in this process, where engineering designers decide on the definitive interior layout while industrial designers determine the definitive exterior form.

The questions about this company include how the process of industrial designers deciding on the exterior and interior of a product at the same time began and why nothing but this process exists.

At first, the process was started by a strong design-first policy in which industrial designers designed the exterior form freely without considering the interior parts, while engineering designers laid out parts inside the form. In the mid-2000s, the former CEO recognized that industrial design would be important for successful product development and enforced a policy of 'adjusting interior parts to outside design no matter what.' Afterwards, the process has been established in a way that industrial designers develop the exterior form and at the same time lay out the interior parts to solve the problems arising when engineering designers arrange the parts inside the exterior form designed by industrial designers.

As design is valued more than any other considerations, and as industrial design teams get influential, some tasks of other departments directly linked to those of the industrial design teams in the process have become incorporated in the job description of industrial designers. That is, industrial designers' roles and responsibilities have extended to planning and design.

Industrial designers' competence in fulfilling the tasks that used to be thought of as those of engineering designers is attributable to their understanding of the interior layout of parts and using the same 3D CAD tools as engineering designers. Using the same tools, industrial designers can effectively present alternatives to problems raised by engineering designers.

The Case of Company C

In the mobile phone market, communication service providers occasionally ask for development of new models in a short period of time or put the design out to competitive tender. It is critical to design a product meeting the service provider's requirements, produce a design mock-up, and participate in the tender, or to respond to the service provider's demand promptly. Thus, when a communication service provider's demand or tender is expected, industrial designers embark upon the design and decide on the exterior form without product plans, specification, or layout data. Strictly speaking, external

demands or tender plans are considered the inputs for initiating a product design despite the absence of internal inputs, which is distinct from the condition under which Company A operates. Notably, the company develops variant models of existing products by changing their exterior styles, which is also different from Company A, which uses industrial design to develop new products.

This process is viable partly due to the nature of mobile phone market, characterized by short cycles of product development, abundant reference products, and insignificant model changes, which enables industrial designers to decide on exterior forms and product sizes based on the existing reference products without product plans or design specification needed for starting a product design.

As it is required to tender for design contracts promptly with a design concept, industrial designers have to produce desirable design outcomes in a very short period of time. Therefore, they complete the exterior form of a product in a short time without any official form, evaluation, or approval. In some cases, they decide on the exterior forms and produce mock-ups within 10 days with a view to winning the contract with the communication service provider.

> An industrial designer: "We often make it happen in a short time as the service providers demand things at short notice in many cases. Skipping sketch rendering and the like, we embark on CAD drawing based on reference phones and send out a phone in three days. At least we have time for producing a mock-up. In case companies are capable of doing that, it takes at least four days to mock up a phone."

Once the communication service provider confirms the design, formal product planning and the process of feasibility testing by engineering designers follow. In this phase, industrial designers coordinate with engineering designers to respond to required design modifications, while engineering designers decide on the interior layout. In reviewing the feasibility, engineering designers try to keep the exterior design as it is to the maximum extent as the design has been confirmed by the service provider. In some cases, the exterior design needs to be changed. The overall characteristics and flow of the detail design phase do not differ from those of Company A. Still, the process runs so fast that the design is on the verge of mass production within a month.

This process is viable against the backdrop of short product development cycles, abundant reference products already developed, and industrial designers' rich experience of homogeneous product design as well as the lack of abrupt changes in product forms, sizes, or functionality. Given the tough competition in industry and the need for short-term development, the company's design team has adopted a design bank concept where plenty of design mock-ups are kept, from which specs and concepts meeting the demands from service providers may be chosen.

The Case of Company E

This company employs a process to develop new models without reference products. Once industrial designers develop the exterior design of a product, engineering designers

implement a product in line with the design to the maximum possible extent. With no reference products, designers roughly decide on target sizes and proceed with concept design. Then, following a formal decision made on commercialization, engineering designers embark on engineering design concept phase for implementation. In this process, they exchange data to decide on the exterior form and the interior part layout.

> An industrial designer: “New projects hardly have some layouts. More often than not, we just develop a design, expecting them to take care of the rest.”
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> An engineering designer: “When developing new products, product planners and designers meet, where designers propose and present an exterior form. Then, we lay out circuits or parts inside the form before confirming and proceeding with feasible aspects. Or, we suggest some parts need scaling up in reverse.”

This process differs from that of company A in that engineering designers give no inputs whereas product planners provide rough data about the direction of design and that development of new products follows the company’s development plan.

3.2 Engineering design-led design process

The Case of Company A

This process is most comparable to this company’s standardized process mentioned by interviewees. Engineering designers lead product development. Still, the importance of exterior forms created by industrial designers is emphasized. This process is used to re-design the next version of a product based on the existing platform of line-up products, or to develop products at the level of a mask change. The process starts by preparing a product planning document based on the annual product roadmap. Then, product planning, engineering design, and industrial design departments have a product planning meeting all together. During product planning, engineering designers decide on the functional and dimensional specification as well as the preliminary layout, while industrial designers use the 3D layout data received from the engineering design team to decide on the exterior form. In this process, industrial designers continuously receive necessary information from engineering designers.

Industrial designers undertake idea sketches, 3D CAD modelling, rendering, design evaluation meetings, and the mock-up selection event to decide on the exterior form design while engineering designers keep evaluating the exterior form developed by industrial designers, and give them advice as advisors. Engineering designers receive the 3D CAD data from industrial designers and test any collision with the layout and feasibility, while at the same time refining the layout so that the interior functions work properly. Overall, despite the preliminary layout serving as the basic information that determines the exterior and interior of the product, both design teams keep interacting with each other to exchange feedback, by which process the preliminary layout becomes the definitive layout while the design sketch develops into the definitive exterior form.

Once the definitive design mock-up and layout are determined, they go on to the detail design phase.

The Case of Company C

This process is comparable to this company's standard process as well. As a rule, the standard process clarifies the period. In fact, the actual development period is shorter than the specified one in the standard process, according to interviewees (product planning: three months + development phase: eight months). Interestingly, this company divides the product development process largely into 'product planning phase' and 'development phase.' The product planning phase involves industrial designers defining the exterior form, engineering designers reviewing the interior layout, mocking up, and the design evaluation meeting. The product planning phase is followed by the development phase, where engineering designers implement the product based on the detail design. The development phase continues up to the testing phase before the mass production phase.

Another distinct aspect specific to this company is the official system called a 'concept meeting' where as part of the 'product planning phase' the product planning team leads a weekly discussion on the advancement of exterior design and interior layout with professionals from relevant departments, i.e. industrial designers, engineering designers, product planners, quality controllers, circuit developers, and hardware developers involved in product development. They discuss and coordinate the interior layout changes and the feasibility of the exterior design developed and refined by industrial designers. That is, in industrial design concept and engineering design concept development phase, multidisciplinary development team experts join to develop an optimized form and layout, minimizing any potential problems that might arise in subsequent phases and increasing the process efficiency.

> An engineering designer: "Usually, multiple departments meet weekly. When something comes up and a decision need be made offhand, related departments meet separately once or twice a week or even daily to discuss whether a design can turn into a real product in terms of sizes to materials, like, about some metal exterior design. Overall, they review the full length, the full width, the thickness, and the specification. Then, the circuit team double-checks the design later on. That's how things go here."
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> An engineering designer: "We co-work with the design team at the concept meeting. That doesn't mean once we give a box (a preliminary rough layout), we just work on the layout only at each session of 10 meetings. That is, after meeting twice or three times, a design gets into shape. Then, we put the design on the layout. With the layout, we scale up or down the size. The meetings go on for co-working on any change of the layout, I mean, discussing whether some parts are in or out, like whether to round it or tuck it in a bit. We optimize things at the concept meeting."

This process seems effective for dealing with tough market competition, short product cycles, and variations of products sharing many platforms.

Both product planning and project managing teams play significant roles in leading the concept meeting systematically.

The Case of Company D

This process starts when the product planning team proposes a product based on the annual product roadmap. Then, engineering designers give the initial layout data called 'box data' to industrial designers. The 'box data' refer to the simplified box-shaped 3D CAD data about the sizes of interior parts. Interestingly enough, once industrial designers decide the design based on the box data will turn out to be uncompetitive in the market, they return to product planning for the spec to be refined. That is, they assess the morphological value of the design right from the start of the design process. Once the industrial design process starts, they exchange data with engineering designers.

Another distinct aspect specific to this company is that experienced and bold advanced engineering designers are deployed to the design department to keep checking the feasibility of design concepts under development. They find out applicable new technology and engineering methods to implement the design concepts presented by industrial designers, while changing and developing the layouts. The advanced technology development function is structured to highlight new concepts of design based on preliminary layouts.

The Case of Company E

This company used this process in two cases. Firstly, some performance issues such as heating found in the existing model for sale should be sorted out in the next model prior to its exterior form design. In this case, a layout is set up to first determine necessary space, followed by exterior form design.

Secondly, for a model whose functionality is considered overarching, its layout is first determined followed by its exterior design. Industrial designers also focus on its appearance rather than a new usability concept.

The Case of Company F

This company is characterized by industrial and engineering design teams belonging to an R&D (Research and Development) division and sharing a workspace. Thus, before a product development is proposed, product planning, engineering design, and industrial design professionals join together to discuss and start basic research. Once the product planning department proposes a product development, engineering designers decide on a preliminary layout based on previous models and pass it on to industrial designers, who in turn design an exterior form receiving data from engineering designers constantly.

Engineering designers keep checking the feasibility and give feedback to industrial designers. This process takes place more personally and closely compared to other companies as both design teams share a workplace.

3.3 Cooperative design process

The Case of Company A

Company A tried this process most recently. This process was applied because a few design outcomes from 'design proposal events' did not proceed to mass production despite good concepts or ideas. The design concepts from design proposal events failed to develop into mass production because no technological support followed to implement the design concepts proposed by industrial designers. An industrial designer in the design team recognized the problem, visited the advanced technology development team, and proposed implementing a new concept together, which was how this process started.

> An industrial designer: "I had worked on purifiers for years. Then, I felt like trying a new advanced product and made a part. I had to run here and there. There are a new product team and an advanced technology team in the R&D centre. I tried to propose co-working to come up with ideas for a new product last year. It occurred to me that a new product would require a team effort between the engineering team, the product planning team, and the design team rather than design proposal events. We did a couple of projects like that."

As the advanced technology development team is in charge of developing new technology proactively, it is less involved in development for mass production, able to more freely and proactively cooperate with industrial designers, and less resistant to adoption of new technology than the ordinary development team. Accordingly, when industrial designers propose a new way to use a product and a novel form, the advanced technology development team cooperates by providing technical support to enable the newly proposed form and functionality. As such, they share ideas and create a synergy effect to develop the form and layout. Such efforts are recognized and well received in the company as well as highly spoken of by the CEO.

This process is characterized by individual initiative, willingness, passion, and efforts by industrial designers followed by the advanced technology development team's support, which led to success without any preset time constraint. Therefore, this process is hardly available to industrial and engineering designers who are directly involved in development for mass production and thus find it hard to spare time.

The advantage of this process lies in the fact that industrial designers break away from the form-based design and come up with a new idea considering the context and usability of a product. Also, this process makes it possible to proceed with design ideas that engineering designers cannot try due to performance or feasibility testing. Conclusively, a new concept industrial designers and engineering designers agree on can be implemented in this process.

The Case of Company D

This process concerns a product development not present on the annual product roadmap, where industrial designers propose a design concept while advanced technology development engineers provide technology as part of a bold product development initiative. This company used this process to develop an innovative new product leading to market success, which facilitated the company's adoption of the new product development process driven by both design and advanced technology development teams.

> An engineering designer: "That's what happened to a phone which had a great market success. The design team came up with an idea for an extremely slim slide phone and we cooperated with the team for the model. When we sent the model to the development team, they just said they could never take or do it because the risk would be so high. They didn't take it and rejected it over and over. So, we were like as they wouldn't take it, we would do it. After all, we struggled a lot. We did it though. We made a product based on the initial design rendering and spec. When we did it, developers were like 'Uh-oh, you did it after all those troubles.' Afterward, they became less resistant to what the design team reviewed and sent and took design plans that would otherwise be rejected because of what they called riskiness."

It is interesting that engineering designers from the advanced technology development team stay together with industrial designers. Thus, industrial designers and those from the advanced technology development team can work as a team, which is suggestive of a few things. First, the existing product development process has so many constraints that industrial designers and engineering designers cannot develop innovative new products. Engineering designers in charge of mass production are under pressure because they should ensure their items pass the performance and reliability tests by the time appointed, which hinders them from trying anything bold or challenging. Also, the innovative design concepts presented by industrial designers can never be implemented without technical support. In this respect, allowing go-ahead to industrial designers and engineering designers from the advanced technology development team to share the workspace and supporting them with a new process will further increase the potential to develop innovative products.

4. Discussion

Companies adopt industrial design-led design process, engineering design-led design process and/or cooperative design process according to their goals and situations. These are the part of their effort to create maximum competitiveness within their situations. Industrial design-led process is applied to produce innovative products with new concepts that achieve aesthetic and usability appeal. This approach was implemented by the CEOs' strong will for acquiring competitiveness of their products by utilizing the sophisticated sensitiveness and user-centred method of industrial designers. This approach will be useful when a company secures high level of technology in design engineering. If it is poor at technology, engineering designers could not implement the design concept provided by industrial designers. Engineering design-led process is mainly used for redesign of existing product. It

implies that the companies adopted this approach to improve product performance quickly reducing potential conflicts with the appearance of a product.

Both approaches inherently cause conflicts between the two groups because one designer group's tasks preceding become to constrain the other's. In this regard, cooperative process, where industrial designers and engineering designers' collaborative work in concept design phase can be a good alternative. Especially, Company D provides a solution direction on this issue. The engineering designers were dispatched on purpose to industrial design department. As a result, both groups of designers increased the level of mutual understanding and developed cooperative process. Furthermore, engineering designers support industrial designers by persuading other engineering designers stayed independent engineering offices apart from them.

Regardless of what approach a company takes according to its situation, the success in product design is dependent on the effective collaboration of industrial designers and engineering designers. In this regard, interdisciplinary education of students who will be involved in product development as an industrial designer or an engineering designer is an important issue. Typical design or engineering education hardly supports this goal. Design education was started in South Korea in the early 1960s from the area of applied art with the aims to support export-driven industrial development in government sector, and with the focus of package designs of products to add aesthetic value. Indeed, its influence has been lasting until today. Nearly, all design schools belong to art schools in South Korea. Product design education is regarded as an art-oriented subject. However, a few universities have brought design departments with engineering fields. Moreover, mechanical engineering departments barely run design-related education. This results in a dichotomized view to design and engineering in South Korea. Indeed, the term 'Engineering design' was introduced quite recently in Korea.

Recently, it emphasized that the integrated education of design and engineering should provide holistic experience of product development process as well as disciplinary knowledge and skills (Kim et al., 2012). Fortunately, Korean government has invested its efforts to change the current art-based design education to be interdisciplinary one by combining design with engineering, business, or other disciplines. This will help companies to avoid conflicts between the two groups in product development. In order to practice the combined design approaches effectively, companies also need to understand the knowledge level of designers and engineers who will work together.

5. Conclusion

Industrial design and engineering design departments work most closely on product design in companies. Design process cannot go forward if these two departments are obscured. Only either one cannot complete product design. However, industrial design and engineering design have been traditionally considered, taught and studied separately. Particularly in South Korea, art-based industrial design education has been dominated and

engineering design has not been well educated. This study viewed product design process as an integrated whole process of industrial design and engineering design and aimed to ascertain how the two fields work in the holistic processes. The author interviewed in-depth with industrial designers and engineering designers from six global consumer product manufacturers in Korean context. As a result, three different types of design approaches were identified.

In industrial design-led design process, industrial designers with no external interference or inputs develop new product design concepts and then engineering designers implement them. Industrial designers never consider technical aspects of interior parts in the concept design phase, which leads to a series of tedious adjustments of design for feasibility in connection with engineering designers. In some cases industrial designers develop the exterior form concept while at the same time laying out interior parts. However in engineering design-led design process, engineering designers make the interior layout based on specifications from the product planning teams, based on which industrial designers define the exterior form. In cooperative process, industrial designers and engineering designers personally collaborated from the start to implement innovative concepts.

The context and purpose of the processes are also different. Sometimes they are used strategically by companies and other times they are applied naturally due to internal and external circumstances. Industrial design-led design process is used in two contexts: 1) when companies are to develop new products distinct from existing products (Companies A and E), and 2) when lots of reference models are available with short product cycles (Company C). Sometimes industrial designers free of engineering designers' influence define the exterior form and mode of use. This process applies when industrial designers work on new products or redesign existing ones (Company B).

Engineering-led design process is used to modify existing products to launch updated products. Mostly, product development scheduled according to annual product development roadmaps follows this process, where unlike the other three processes engineering designers play prominent roles from the outset.

Cooperative design process is used to develop innovative products when industrial designers with a good design concept in mind receive technical support for implementing the concept from advanced technology development engineering designers.

Companies should effectively utilize industrial design and engineering design. The research results provide useful insights for companies when they plan to adopt certain strategies. However, to support company's design management better, deeper understanding of each approach, such as strengths and weaknesses is needed. Also investigation of conflicts, causes of conflicts, and resolution strategies in these processes will support the development of better design management strategies. Extending the research issue based on this, the pedagogy of integrated education of design and engineering education is

substantial. Finally, further study needs to explore other countries' cases to see if the three design approaches are applicable in general.

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