Viewpoint: Design and Engineering Convergence Education in a Korean and Australian Context

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Abstract

Background In this article, we provide two views on product design engineering education of two design educators from Korea and Australia. We argue that industrial design and engineering design need to be combined in order to support a total design philosophy that aims to improve design education. Therefore, the changing direction of design education for a total design perspective — and Korean and Australian design education — including industry situations are discussed. Product design education in Korea has focused on developing the physical appearance of a product. The concept of engineering design was recently introduced in Korea, and most design schools still belong to art schools. Nowadays, Korean industry is required to develop new businesses in the manufacturing sector, as the industry is facing the situation where 'fast follower' strategy does not work for sustained growth and ultimately sustained success. This has grabbed the attention of product design engineers who can develop creative designs and materialize the concepts. In contrast, Australia is facing the end of a mining boom as well as a significant decline in automotive manufacturing. This has forced industry to challenge innovation in manufacturing which has generally been made up of SMEs. As such, the role of product design engineering is emphasized. We conclude that product design engineering education with industrial design and mechanical engineering can be primitive to strengthen the competitiveness of the manufacturing industry in both countries.

Methods The views provided in this article were assembled from the existing literature, and based on our current experience of running design engineering convergence education programs in undergraduate and graduate levels. In general, the arguments made in this article are not attracted from theoretical and empirical research. They are rather based on our own perspectives of design engineering education. Thus, the views can be more critically based on holistic analyses of industry situations.

Results & Conclusions In this article, we examine that how a strong and well-defined product design engineering program within a university context can add significant value to the industry. Product design engineering is a hybrid program that combines analytical engineering sciences with creative industrial design capabilities. It provides a platform that can reshape product offerings for companies that seek to diversify or expand into new markets. Product design engineering links seamlessly toward current industry needs by producing creative design engineers at the forefront of innovation and new product development.

Keywords Product Design Engineering, Korean Design Education, Australian Design Education, Korean Industry, Australian Industry

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1. Introduction

How can product design be adapted in and contribute to future society and industry? It is important to note that universities represent the principal player in society transformation, because they train the future workforce and the leaders of tomorrow, setting 'the knowledge' as the primary factor of production in the global economy (Rajasingham, 2009). This transformation can be structured by the implementation of new learning strategies, shape new knowledge and put into practice to educate the next generation of leaders. Thus, education in university cannot be conceived apart from the current and future society and industry. Experts trained within the university who contribute to the transformation of society and industry is critical in creating a knowledge economy and a strong manufacturing base.

A product design discipline involves the creation, production, and use of products that have a direct connection with industry. This implies that the change of society and industry requests to change product design education. The recent emergence of interdisciplinary education in design, particularly in Korea can be seen as a phenomenon of the change driven from the society and industry. There have been design schools that execute multidisciplinary education. TU Delft in the Netherlands, arguably has one of the strongest integrated industrial design and mechanical engineering programs in the world, and bases their program off a multidisciplinary learning platform that uses project-based learning as the main academic methodology and structure of the curriculum. TU Delft allows students to learn from different disciplines such as Engineering, Manufacturing, Ergonomics, Design, Marketing and Consumer Behavior and Sustainability (TUDelft, 2016). The main idea is that students can fully understand all different disciplines involved and enable them to develop new products and services with a focus on innovation. Other design-engineering convergence education institutions, include a Product Design Engineering program jointly run by University of Glasgow and Glasgow School of Art, an Innovation Design Engineering program jointly run by Royal College of Art and Imperial College London, Integrated Product Design at Brunel University, Industrial Design & Technology in Loughborough Design School, and Product Design at Stanford University.

Unlike European countries that have practiced multidisciplinary design education of design and engineering for a long time, the recent situational change in industry in Korea and Australia creates higher demand in the design-engineering convergence education than ever before. The Korean government has driven design-convergence education for the past ten years to support industry change (MKE, 2013). Recently, it has driven design engineering education to enhance Korean manufacturing competitiveness (MOTIE, 2014). Australia has relied on the mining industry over the same period. The mining boom is over and Australians need to prioritize the knowledge of its people to help retain manufacturing jobs in an ever-increasing competitive environment. There has been increasing discussion of creating new businesses based on new product and product services based on manufacturing. To set up the design engineering education, we need to carefully understand one nation's societal and industrial change. Building connection between university education and industry change is the best way for the university to train industry leaders and educate the leading player in society transformation.

This article is not a research report deriving out of theoretical or empirical study. Yet, based on our experience and literature review, this article provides our viewpoints of design engineering education for product design education direction to proactively cope with each country's industry situation. Although, Korea and Australia have different major industry fields, it is interesting to observe how situational change can lead both countries to go toward similar directions in design education.

This article is composed of five parts. After this introductory section, the second part discusses 'product design' from academic and industry perspectives. It describes the difference of design from other disciplines in terms of knowledge accumulation and delivery, and the reasons why design education should be changed. In the third and fourth section, we provide our own views in each country's design education, industry situation, and design engineering education direction. The last section summarizes the conclusion of these views.

2. Necessity of design engineering education

2. 1. Knowledge in design

Should design education be practiced in an integrative way? If it should, what should be integrated and why?

Owen (1998) introduced a general model for generating and accumulating knowledge, and extended it to explain design research. He described that an academic discipline creates, accumulates, and uses knowledge with activities in the realms of theory and practice. Realm of theory is the domain where knowledge is accumulated through finding and discovery, while the realm of practice uses invention and making to accumulate knowledge. Owen (1998) showed how various disciplines, such as science, engineering, art, music, and design could be explained by this model.

Education is rather delivering knowledge than creating and accumulating. We need another approach to support education. In realm of theory where finding and discovery is the paradigm, knowledge delivery is usually practiced with textbooks through lectures. In contrast, realm of practice where knowledge is created and accumulated through invention and making (creation) should use practice as a means to deliver knowledge. Understanding these two is important to discuss how design education should be practiced.

The knowledge accumulated through finding/discovery and invention/making is categorized as declarative knowledge and procedural knowledge. Declarative knowledge is factual information that is stored in memory (Anderson, 1990). For instance, math equations, or scientific facts and theories. Other names are descriptive knowledge and propositional knowledge. One can learn this type of knowledge through understanding and memorizing. Thus, reading, taking lectures, and memorizing can be the main activity to learn such types of knowledge.

In contrast, procedural knowledge is the knowledge of how to perform, or how to operate (Anderson, 1990). Therefore, Know-how is another name. Acquisition of procedural knowledge requires repeated practice. For instance, one could explain how to skate after reading a skating training book, but could not skate without practice. It is said that one becomes more skilled in problem solving when he/she relies more on procedural knowledge than declarative knowledge. The discipline of design definitely has strong aspects of realm of practice in accumulating knowledge. Thus, education should be done through training and practice (Lawson, 2006). Thereupon, the way of practice can be an issue. For instance, product design knowledge can be articulated in several sub-skills and knowledge such as knowledge related to conceptualization, drawing, embodiment, implementation, etc. Even if one learns all sub-skills, it does not mean he/she can perform product design. He/she needs to learn another skill that can connect and integrate the sub-skills seamless. This is why design education, whether or not design engineering education, should be practiced in an integrated way. This implies that product design education should include two approaches; one is to teach sub-knowledge, the other is to teach the way of integration of the sub-knowledge. It means that students need to experience from creating an artefact to delivering it in an integrated way. This kind of education inherently requires multidisciplinary knowledge and skills, and knowledge to integrate them.

2. 2. Product Design

Industrial design and engineering design take an essential role in the actual product design process (K. M. Kim & Lee, 2010; Lindbeck & Wygant, 1995). However in many cases, industrial design and engineering design have been educated separately (Horvath, 2004; K. M. Kim & Lee, 2010). Industrial design emphasizes user experience and aesthetic appeal of a product while engineering design does technological functionality (K. M. Kim & Lee, 2010).
Product design often means in another way 'product development' (Hollins & Pugh, 1990; Pugh & Clausing, 1996; N. F. Roozenburg, Eekels, Johannes, 1995). This perspective comes from total design that describes design process as the integrated activities of product planning through production to sales in marketing activities. In this perspective, engineering design, industrial design, ergonomics, marketing and innovation management are the disciplines that nearly constantly involved in product design (N. F. Roozenburg & Eekels, 1995). Thus, multidisciplinary approach is the main idea in this perspective. This reasonably includes not only product design, but also product engineering (Pugh, 1991).
From this setting, the direction of product design education becomes clearer. Conventionally, product design has been the subject of industrial design and engineering design (or mechanical engineering). In this approach, knowledge and skills necessary at each product development stage are taught separately. Industrial design teaches more about knowledge necessary for conceptualizing products for user-centered design, while engineering design/mechanical engineering does for embodiment and implementation.
The multidisciplinary design education in line with total design requires integrative knowledge of industrial design, engineering design, and business studies.
The strength of such education is that students can perceive and handle the overall background of product development, while the weakness is that it will probably take longer to be educated. One option is to teach disciplinary knowledge in separate disciplines in undergraduate level and integrate them in a graduate program.

2. 3. Product Design Engineering

Product Design Engineering is the convergence of two diverse disciplines — Mechanical Engineering and Industrial Design — with the intention of training a qualified engineer with a comprehensive understanding of applied industrial design. It is claimed that product design engineering is one of the key disciplines required to transform industry by having the necessary design and engineering skills to promote innovation.

The benefit of interlinking these traditionally separate disciplines is to ensure a product design engineer can directly apply engineering theories/knowledge to product outcomes by having the ability to think creatively and analytically at the same time. This single most important characteristic is what differentiates a product design engineer to a straight industrial designer or mechanical engineer. This is not to suggest that mechanical engineers and industrial designers will become obsolete; the role of a product design engineer in the design process fills the gaps between both disciplines to appreciate the aesthetic qualities and user interactions of a product, while at the same time having a primary emphasis on functional utility and manufacturability. Moreover, product design engineering crosses over to social sciences by requiring an understanding of users and other influential indicators that interact directly with the product design engineering outcomes.

Figure 1 visually represents where product design engineering fits within the context of other discipline areas. This visual (adapted from Dixon, 1966; Hundal, 1997) is widely recognized as an accurate visualization of where product design engineering 'fits' within other disciplines. Unlike the visual depiction by Hundal (1997), Figure 1 focuses specifically on product design engineering and has been adapted to show the linking disciplines of product design engineering. Figure 1 clearly shows that product design engineering is an important core discipline that is accurately multidisciplinary and an important link for innovation to occur.

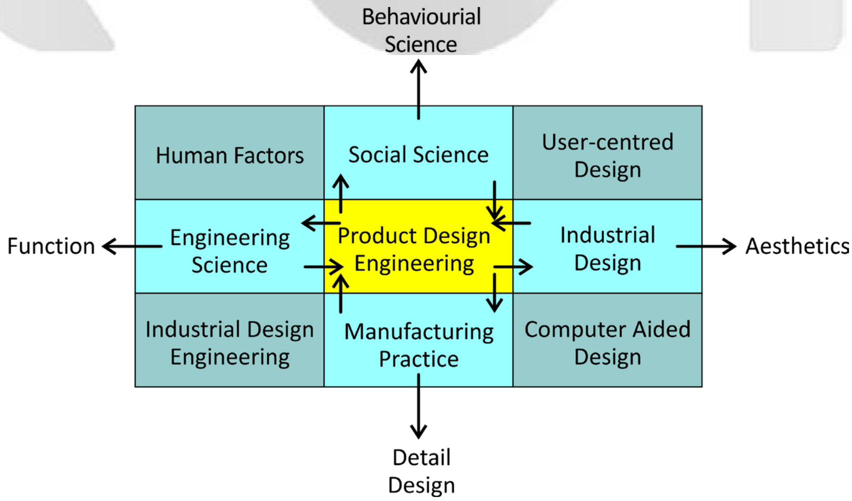

Figure 1 The influences and connections of product design engineering in a product development context (Adapted from Dixon, 1966, in Hundal 1997, p. 38).

The 'design process' between an engineer and a designer shares common grounds but have various differences. An industrial designer is constantly thinking about the final product outcome and its communication throughout the whole design process with a stronger ability to tackle the front-end of a design project. A mechanical engineer is more concerned with the product functionality/performance with the anticipation of developing concise outcomes in preparation for the product's manufacture. Product design engineering can be seen as a dialogue between both disciplines with expertise in both the development and execution of a product, while at the same time having an understanding of social sciences and manufacturing practices.

The integration of industrial design and mechanical engineering develops creative and adaptive engineering designers who have unique engineering pedagogics, including 'designedly ways' of thinking, which is a phrase coined by Cross (2001). Kuys, Usma-Alvarez, and Ranscombe (2014) summarize the similarities and distinctions between product design engineering, mechanical engineering and industrial design from a design perspective: An industrial designer focuses on the product outcome and its development process, whereas a mechanical engineer is mostly related with the functionality and performance of the product. de Vere (2013) considers mechanical engineers having high levels of engineering science knowledge, technical understanding and analytical skills; however, they lack creativity and design skills. Promoting creativity is the biggest challenge when teaching a design approach to engineering students (Kuys & Vere, 2010), however this is fundamentally important to promote an innovation agenda.

3. View on Design Engineering education in Korea

3. 1. Design Education in Korea

Korean design education is originated from applied art with the beginning of industrialization (J. Kim, 2008). Thus, it is characterized as art-oriented subject. Indeed, design subjects are dealt with in art classes in primary, middle and high school(MCST, 2015). Almost all design related departments in higher education belong to art schools. The 2014 government survey shows 907 design-related departments belong to art school, but only 49 belong to non-art school (KIDP, 2015b). Not all 49 belong to engineering school, but some schools offer design education in engineering schools. It is hard to say that they offer true engineering-oriented design education. Undoubtedly, the term 'engineering design' was introduced in Korea in 2010.

There are two Korean words indicating 'design' in English. The one is '디자인' (pronounced as 'desain') the other is '설계' (pronounced as 'selgye'). People think '디자인' as an art-related field, such as decoration of appearance, packaging. In contrast, '설계' is considered as a part of engineering. There is a little notion of design in '설계.' Any discipline with the term '디자인' is officially classified as an area under 'Art' in the taxonomy of academic research field (NRF, 2016).

This means that Korea has a big perceptual difference of design from western countries where design has more holistic meaning about the subjects of art, engineering, and social innovation, etc. (Ulrich, 2011). In Korea, art-oriented researchers have mostly operated almost all academic design research societies. In contrast, 'The Design Society' in Europe focuses more on engineering design (TheDesignSociety, 2016), and 'Design Research Society' covers more comprehensive and interdisciplinary design areas (DRS, 2016). Due to this difference, there have not been many Korean design researchers contributing to 'ICED' or 'the design conference' hosted by 'The Design Society.' To sum up, art-oriented design and engineering in Korea have been dichotomous while engineering design is just growing.

3. 2. Contribution and Limitation of Korean Design Education

For the last 60 years, adopting the 'fast follower' strategy, Korea has developed its industry through simulating new products developed by advanced countries (C. Sung, 2015). Designers educated from art schools can quickly benchmark advanced products and contribute to develop new Korean design styles. As a result, art-oriented design made a big contribution to raise the visual quality of Korean products to the extent of those from advanced countries during the industrialization period.

Development of new design concepts and its visualization is the main training point in art-oriented design education. The concept development is generally limited to defining form and user interaction. The conceptual design in engineering design that defines functional requirements and develops working principles are not the main focus. Most design outcomes are visualization of concepts or non-functional 'dummy' mock-ups (Hong, 2007). Recently, there are increasing cases in design schools that develop working prototypes with electronics and programming techniques – for instance working with Arduino boards (e.g. (S. Kim & Kim, 2015; C. Park & Lee, 2014)). Although, the limitation is still vibrant, because mechanical functionality and manufacturing aspects of product design are not mostly included in the design education subject. This has been one of the main causes that product designers have trouble in communication with engineers, and suffer from a lack of understanding of functional and technological knowledge for a couple of years, while they have adapted themselves to product development environments (K. Kim & Lee, 2014).

The main industry in Korea is manufacturing. There are a small number of complete product manufacturers, most of which are conglomerate, and huge numbers of suppliers that are SMEs supporting the manufacturing industry (Han, 2006). The complete product manufacturers maintain full product development cycles with various experts of marketing, design, engineering, etc. Each expert group's tasks are functionally specified. Industrial designers do not need to consider numerical marketing data or technical aspects of design concepts. Their job is typically to develop the external shape of a product that predominately starts with receiving pre-determined design concepts and specifications from marketing experts and/or engineers (Hong, 2007). In this environment, their restricted task causes no problem because tasks before and after industrial designer's jobs are well managed by other experts (Ahn, 2016).

SMEs that make up the majority of Korean manufacturers have a very different situation. Most of them do not have full product development cycles (Han, 2006). In many cases, their production of new components starts with receiving engineering drawings from a big company. To keep their business in relationship with the big company, they do not need to have planning, design, and marketing experts. Thus, there has been no demand for designing new products.

While, Korea was in an economic boom, there were many demands of design development from complete manufacturers. The number of design firms was 910 in 1997 and increased to 2,245 in 2005 (KIDP, 2015a). Design firms could maintain their business relying on them, however, the form of business was limited: a client manufacturer usually requests mainly exterior design of a product based on previously decided product concepts and specifications (Y. Sung, Cho, & Ro, 2014). In this kind of business, design firms should be dependent on client companies. They have rare chances to propose their own design concepts to clients.

Although, design education in art schools teaches new concept generation intensely, the problems seem to lie on the lack of education about functional and technological concept development and its implementation in a commercial environment. Particularly, mechanical (further mechatronic) functionality and manufacturing technology seem to be the weakest part. If someone proposes a wonderful design concept of a product without any technical solutions for implementation it would just be a fantasy. Even if the visual representation of the product is fantastic, no engineer is willing to tackle the unidentified technical problems behind the concept. Furthermore, there will be no blind investor who will be willing to commercialize the conceptual product without any technical verification. This education limitation seems to be one of main causes that there have been few start-up companies that product designers have founded and extended. As the economy situation changes, exterior design-oriented product designers will hardly survive. This calls for the education change in design schools.

3. 3. Industry change and the direction of design engineering education

The Korean economy relies on manufacturing. Although, there are many demands emerged on design business in other domains, design industry should strongly support the manufacturing area in order to boost Korean economy (KOTRA, 2008; K. Park & Son, 2007). Product design educators should understand the environmental changes in industry and design new education programs for the future of Korea. Now, Korean industry reaches up the level as of advanced countries, and the low growth trend is noticeable. There are no target products that the complete manufacturers can copy and follow. This change has led to changes in the overall industry in Korea.

Big complete manufacturers are under pressure to develop new products that were not seen so far. This could not be achieved with the current organizations that are optimized for a fast follower strategy.

To be a ‘first mover’ the companies should be flexible and quicker like a venture company. SMEs are also placed in the difficult situation to survive as suppliers to large companies in this slow-growing era. This drives the companies to challenging situations where they have to open up new markets with entrepreneurship (Kang, 2012).

The new paradigm that shows companies should be devoted to the development of items for opening up new business, requests designers for different expertise from current ones. Product designers should be involved in planning new products, creating technical as well as appearance concepts, and developing working prototypes.

In order to raise new types of designers, an integrated approach in design education is necessary and requires combined education of industrial design, mechanical engineering and business. In this training system, students need to experience the overall product development process from creative concept development through implementation to developing business models. The designers raised through this education are not simply exterior designers, but project managers who can manage a product development project. With regret, there have been few designers as a project manager. Engineers or marketing experts have usually taken these positions. Now, we need to raise designers as project managers.

Through this article, we call the designers who are trained in this education as 'design engineers.' Design engineers can be equipped with the ability to develop, implement, and commercialize creative design concepts. Thus, they can play a central role in opening up design-driven new businesses. In a big company, a design engineer can coordinate product development project and can take a central role for SMEs desire to develop new products and open up new businesses. Thus, they can manage their businesses more proactively as product development consultants.

We need to change the risky Korean economy structure where the Korean economy itself and a majority of SMEs are under the substantial influence of a small number of big companies. One direction is to raise hidden champions among SMEs (Lee, 2014). The greatest potential of the new education is the increasing possibility of emergence of new business. Empirical knowledge about product development that design engineers occupy will provide them with more opportunities to grow as entrepreneurs opening a new business. Taken all together, ultimately, the integrated design engineering education will contribute to rising up hidden champions in manufacturing, such as the next Dyson company in Korea. This will change the Korean manufacturing industry to be more creative and strong.

4. View to Design Engineering education in Australia

4. 1. Design Education in Australia

It is claimed that product design engineering is the key to boost innovation in the manufacturing sector. The problem is that there is not enough awareness of this from the Australian government, from universities, from industry, and most importantly at a high school level. The key barrier that currently exists in Australia is the lack of awareness of product design engineering at a high school level. The high school subjects focus heavily on STEM (Science, Technology, Engineering, Math) programs and when it comes to design, the majority of high school students choose visual communication (graphic design), as this is common to all high schools and seems to be the default subject for students who have an interest in design. Product design engineering requires skills in both the STEM subjects and the design subjects, which is difficult because Australian high school students usually do one or the other – not both.

According to the Design Institute of Australia(DIA), there are an estimated 5,939 registered graphic design companies, compared to product and industrial design where there is an estimated 360 (DIA, 2015). Further to this, between 1991–2011 graphic designers in Australia grew from 8,620 (1991) to 25,507 (2011). To contrast this, product and industrial designers grew from 1,375 (1991) to 2,931 (2011). In an era where product and industrial designers — and product design engineers — are seen to be in demand to drive innovation and creativity, numbers in these disciplines simply have to grow. Whilst, visual communication (graphic design) is clearly important, it is fair to say that there is currently an imbalance in 2D and 3D design expertise, which is largely attributed to Australian high schools focusing more on visual communication rather than product and industrial design. However, taking the employment statistics above, it shows that on average there is a ratio of 8:1 industrial/product designers per registered company compared to that of visual communication design, which has a ratio of just over 4:1. It is assumed that these figures are distorted, as there are many industrial/product designers working in industry sectors, such as manufacturing that are not counted as an industrial/product design company. However, the 3D design disciplines still require expansion and greater awareness of the value of product design engineering to grow an innovation economy is needed.

At a university level, product design engineering is also being neglected as there is only one truly integrated program in Australia merging the analytical engineering sciences with the creative industrial design skills (S. Univ., 2016). There are double degree programs between industrial design and engineering (M. Univ., 2016) and merged programs between electrical engineering and industrial design (RMIT, 2016), but none that focus specifically on innovative product design through the convergence of industrial design and mechanical engineering.

4. 2. The importance of product design engineering education in Australia

For Australia, this is vitally important, as the terms of the trade boom have come to an end. To continue to prosper, Australia must find new sources of wealth. As an advanced economy, Australia expects that further advances in national competitiveness and economic growth, including employment growth, will come primarily through innovation. Innovation is the core driver of business competitiveness and productivity. It supports economic growth, exports and job creation. Facilitating innovation involves enabling disruptive technologies and globalization to access more opportunities for new products, new industries and new markets (OCED, 2015).

An indication of business performance and growth, which is fundamentally important to the Australian economy — is the range of goods and services that a company offers to consumers. An increase in the range offered is indicative of expansion. This expanded range may encompass products that are very new to the industry/market or they may just be new to the company. An expanded product range may indicate business dynamism as it would potentially diversify the company's sources of income from sales and may indicate buoyant demand conditions in the companies' market (OCED, 2015). This report from the OECD Innovation Strategy (2015) is good in principle but it only explains 'what' is required for economic sustainability and not 'how' it will be done.

The answer is in increased support for companies to have the means for engagement with product design engineering to enable new product development. This is not currently occurring, as R&D budgets in Australia are minimal and Figure 2 shows that established companies are not investing in new product development as if they should be.

SMEs in their first year of operation is overall more likely than older firms to introduce new or significantly improved goods and/or services. In 2012–13, nearly one quarter (24.2 per cent) of Australian businesses aged less than one year (with 0-199 employees) invested in such new products. This declined to 13.6 percent for mature SMEs aged 10 years or more (ABS, 2015). This relates to established markets where mature companies may not feel the need to invest in new products, however, these companies should not be complacent and the drive for innovation should always remain.

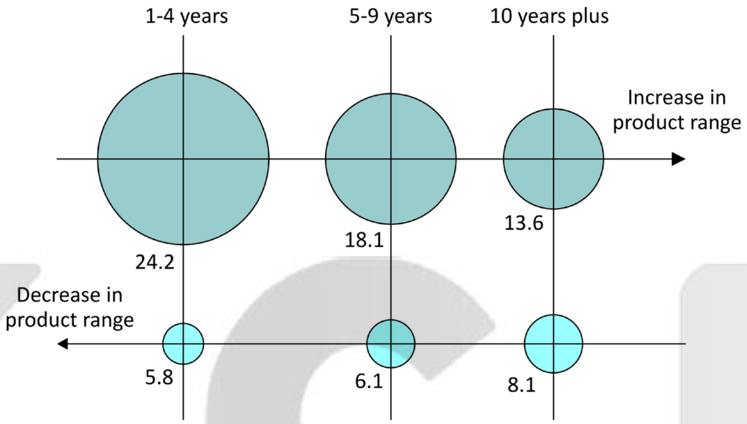

Figure 2 Percentage of SMEs that increased or decreased the range of goods and services offered over previous year, 2012–13. (Source: Australian Bureau of Statistics (ABS) Business Characteristics Survey: Customized Report, Table 6.)

Product design engineering is required to boost innovation in industry, however this is also required to convince industry of its importance. The greatest barriers in this field of research are convincing manufacturers the value of product design engineering. There is an appreciation of design within many manufacturers; however, the value proposition is often hard to overcome.

The organizational context and current issues the manufacturers are facing economically are as follows:

- A lack of design integration in their current business models
- No previous need for design integration
- An appreciation for design intervention but no understanding of how to do this
- Too risk averse
- Minimal R & D budget
- Often more in the 'S' category rather than the 'M' category when relating to SMEs

The above points are difficult to overcome when dealing with companies that have never engaged in product design engineering before, however if these companies do not change, they may cease to exist. The simple problem with this complex issue is the majority of products these companies are producing are simply not required anymore. They need to understand their core values while being open to change to ensure financial stability.

In a quote from Bucolo and King (2014), wherein they stated that to remain competitive, many Australian companies need to transition from their traditional business models to those centered on high value-added product and service 'solutions' that compete on value rather than cost alone.

High value manufacturing focuses on the company managing its intangible assets of brand and image, research and development, intellectual property, market intelligence, product/service packages, marketing and logistics, customer relations management, and its human and organizational capital (Bucolo & King, 2014).

Australian manufacturing needs to be smarter and understand successful manufacturing models from similar (expensive) countries around the world. An example can be seen with the Swiss who continually inject design innovations in the front-end of manufacturing activities and ensure quality is not compromised in any way.

"Switzerland is like a Silicon Valley for the manufacturing industry. Given the higher cost base, no Swiss manufacturer would survive if it were not world leading or top quality. The focus on high-quality engineering and design allows companies to compete with cheaper products from emerging markets (Koch, 2015)."

The clear goal of this article is to legitimize product design engineering and show the value this discipline can add to manufacturing companies. Researchers who "engage in doing design work... directly impact practice while advancing theory that will be of use to others" (Barab & Squire, 2004). Product design engineering practice is beneficial to industry by developing appropriate artefacts used to generate a new body of knowledge created from the extensive hybrid knowledge between industrial design and mechanical engineering. Then, it can lead to new markets that were previously not thought of by the companies involved, as a large majority of companies has never had to do this before. This enables diversification of product output and provides new market opportunities to often dying industries.

"(Intellectual capital) is becoming corporate America's most valuable asset and can be its sharpest competitive weapon. The challenge is to find what you have – and use it" (Steward, 1994 in Roos, Roos, & Kennedy, 2014).

As in above, while dated, should be applied to Australian manufacturers in the same manner to increase the competitive awareness of the company and use the skills and knowledge that exists.

In an educational context, linking learning to emerging spheres of influence and ensuring a level of agility is of great benefit. Traditionally, product design engineering education is taught in a studio/tutorial environment and is relatively quick to evolve to new demands placed upon it. The content of the product design engineering programs is strongly influenced from external factors; from new manufacturing techniques, such as the emergence of 3D printers and the prevalence of Computer Numeric Controlled milling stations — to the growing needs of the marketplace and new industries. There is a strong need to ensure that learning outcomes and materials are up-to-date and in many cases, ahead of industry demands and requirements.

5. Discussion and Conclusion

This article presents our views on design and engineering convergence education in a Korean and Australian context. It emphasizes the importance of integrative product design education based on the analytic argument about total design approach in product design education. We also defined and discussed about product design and product design engineering. To provide substantial perspectives, we analyzed Korean and Australian design education and industry changing situation, and provided our viewpoints on the direction of product design engineering education.

As this article does not present a research result but views, our experience and perception along with related literature are the main basis for the arguments made in this article. Thus, we do not intend to generalize our arguments but want the readers to gain insights and sympathy.

Nowadays, the industry requests product designers for a variety of skills to develop new products. Product design engineers should be able to present technical solutions for implementation, as well as generate novel design concepts. In order to foster product design engineers, not only disciplinary specific knowledge of design and engineering but also integrated knowledge of them should be educated. It is important to provide a holistic experience of the product development process for the students. Pedagogically, this needs to include the practical training courses of creative idea generation, aesthetic form development and problem identification. In addition, the education needs to include teaching scientific principles and theories to solve technical problems and to implement a design concept as a working prototype with commercial potential.

There are still some issues remaining. If we combine industrial design and mechanical engineering in an education program, we should reach a consensus on education philosophy and practice among design and engineering teachers. More than that, there needs to be at least one leading person who can understand and experience the overall product development process. Besides, schools need to provide actual design problems and enough budgets for practical activities, such as building functioning prototypes. One feasible solution is to bring companies' design problems into the classroom. Students could take advantage more if the companies support necessary budgets.

What seems to be clear is that manufacturers could benefit from having exposure to the latest forms of innovation best practice drawing from the unique nature of product design engineering. The role of a modern designer is to ensure that products and services deliver so much value that they sell themselves. A product design engineer links between many disciplines and has the ability to generate novel, innovative ideas with commercial merit. A good product design engineer is capable of developing desirable, functional products that people want, which for the manufacturing sector looking to diversify is exactly what both Korean and Australian economy's needs.

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