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A look at the research on design idea generation in industrial design: Literature review from 2003 to 2017

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Abstract: Design idea generation is a significant part of industrial designers work and most frequently associated with creative problem-solving. Moreover, design idea generation is a process rooted in individual knowledge and is often considered a precedent-based type of reasoning, where knowledge is continuously transformed to produce new insights and is perceived to be challenging to the industrial designer. This paper reviews the literature on idea generation in industrial design area from 2003 to 2017. The goal is to understand what happened in the ideas' generation process in the industrial design area. Most papers have focused on when and what designers look for when searching for inspiration. Nevertheless, the reasons behind of the different sources used during idea generation phases are still unclear. The knowledge transformation with appropriate methods needs to be clarified so that designers know how to make use of various sources to generate ideas more effectively.

Keywords: *design idea generation, industrial designer, design sources, design tools*

1. Introduction

With the point of view of Tim Brown (2009), CEO of IDEO, design projects develop through three stages: inspiration, ideation, and implementation. Inspiration means gathering insights from every possible source and identifying an opportunity, whereas ideation means translating insights into ideas and conceive general solutions. The function of research in the design ideas generation process, which runs from inspiration to ideation, is to ensure the evidence and insight obtained enables the designer to answer the initial question as unambiguously as possible (De Vaus, 2001). The quality and effect of research ultimately affect the design process because it helps define the challenge and the way problems are solved (Singer, 2003). Within the design thinking tradition, it is the designer who generates, selects, tests, and refines ideas as a means to improve the design problem and arrive at an effective solution. Thus, it is important for designers to understand how they influence this process via generating creative and innovative design ideas (Gonçalves, Cardoso, & Badke-Schaub, 2014). And this is crucial because design idea generation is the activity most frequently associated with creative problem-solving. Besides, the ideas generated at this stage are used throughout the creative process. Taking the idea generation phase seriously is central to the success of the creative problem-solving process. However, there is still no overall consensus on how best to incorporate the inspirational materials and fieldwork data into the idea generation process. The research literature on design ideas generation is still emerging, and more attention needs to be put on sources and corresponding approaches that designers use to generate ideas, as well as insights into how they characterize and

understand their individual idea generation process (Hutchinson & Tracey, 2015). We, therefore, investigate the situation of ideas' generation in the industrial design area. The research question guiding this study is as follows: What is our current understanding of the design ideas' generation by industrial designers in the past 15 years? Through examining the literature, we try to get a better knowledge of what we already know from the previous research and what we need to know while planning research for the future.

2. Methodology

From a methodical point of view, we performed a literature review as "a systematic search of published work to find out what is already known about the intended research topic" (Robinson & Reed, 1998), to provide "an informed evaluation of that literature" (Power, 2012). Based on our investigation of design ideas' generation by industrial designers and the database "Elsevier" and "Taylor & Francis Online", the number of papers in this field has been searched with a search using the keywords "idea generation". We mainly reviewed articles in online peer-reviewed journals as these articles have been examined and reviewed by several outstanding scholars who make papers more rigorous and certified. The three journals were found to have more papers included relevant to our research question: the Journal of Design Studies, International Journal of Design Creativity and Innovation and the Design Journal. The first one is a leading international academic journal focused on developing the understanding of design processes, the latter two are also the international refereed journal, which both discuss the methods and potential of creativity in design from both theoretical and practical perspectives, and the last one is also the journal of the European Academy of Design. Based on the keywords 'idea generation', there are 561, 68 and 602 papers located respectively. We firstly removed the duplication and irrelevant ones, and then continue to narrow down the results by limiting the date range from 2003 to 2017. And as we try to focus on industrial design including product and interaction design area, we, therefore, discard contributions such as mechanical, interior and architecture design, etc. Besides, idea generation is relevant in many design phases, we focused on the phases from the inspiration to ideation. Then there are 9, 3 and 2 papers respectively remained. After that, to maximise coverage, we also conducted reference list analysis and searches on included articles and assessed identified papers against the same eligibility criteria. Another 17 journal and conference papers were also chosen which present up-to-date research and work on the research topic. Finally, 31 articles were included in the sample.

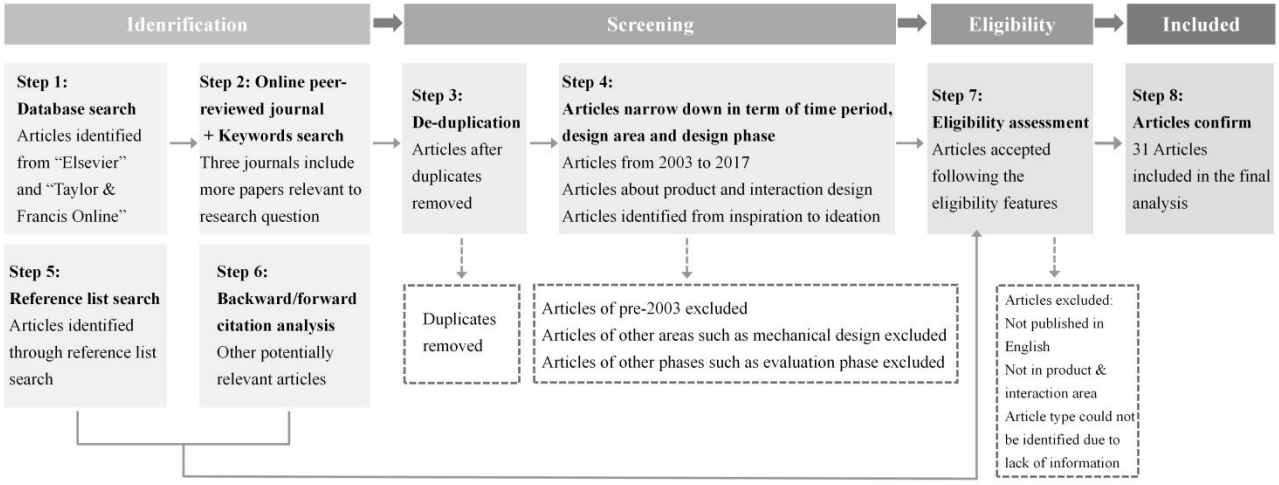

Figure 1. Flow diagram of systematic review process

3. Findings

For a better understanding the ideation process from inspiration phase, the method we use to code the paper content is the framework of 'when, which, what, who' to analyze the design ideas generation process, which enable us to develop a deeper understanding of how to position the paper content and

to find out what is going on to establish an optimal entry point to analysis. Therefore, given what appeared in the literature, the finding section was sorted into categories as follows: (1) When - The timing of design idea generation, (2) Which - The tools helping to generate design ideas, (3) What - The external sources used by designers to generate ideas, (4) Who - Compare design ideas generation among different groups. The subclassification identified from studies on each category are also presented below. Table 1 lists the reviewed articles' main categories and subclassification about design ideas' generation arranged by year. After presenting the research findings, the conclusion and implication for further research would be discussed accordingly.

Table 1. Reviewed articles' main categories about design ideas' generation arranged by year

		When		What (source)							Which (tool)						Who				
				Type of source					Effect of source		Traditional tool						Different level of designer				
Year	Author	Unintentional	Intentional	Pictorial	Textual	Verbal	Tangible	Others	Positive	Negative	Sketching	Collage	Storyboard	Prototypes	Digital Tool	Others	Expert	Professional	Student	Novice	Others
2003	Tovey et al.			●					●		●				●			●	●		
2004	Cross		●				●		●	●	●					●	●				
	Petre	●	●					●	●							●	●				
2006	Mckay		●	●		●			●	●		●							●		
2007	Perttula & Sipila							●	●	●											
2009	Herring et al.			●			●		●					●		●		●			
	Saunders		●						●			●	●			●					
2010	Smith et al.	●	●				●	●	●	●											
	Goldschmidt et al.				●				●								●		●		
	Cai et al.	●	●	●	●			●	●								●			●	
2011	Gonçalves et al.	●	●	●	●	●	●	●	●	●							●			●	
	Mcginley et al.		●		●	●		●	●						●	●		●			
2012	Gerber					●			●					●				●			
	Hallgrimsson						●		●					●	●			●			
2013	Viswanathan et al.			●			●		●	●					●					●	
	Zhao	●	●					●										●			
	Pniewska et al.		●						●	●				●					●		
	Pan et al.										●				●				●		
2014	Gonçalves et al.	●	●	●	●	●	●	●	●	●		●	●			●		●	●		
	Laamanen et al.			●		●	●	●	●		●					●		●			
	Chansri et al.			●			●		●		●				●						
	Sas et al.		●				●	●	●		●			●	●	●	●	●			
	Vijaykumar			●	●			●	●						●			●	●		
2015	Hutchinson et al.		●		●			●	●						●	●			●		
2016	Vasconcelos et al.		●	●	●		●	●	●	●							●	●	●	●	
	Han et al.		●					●	●						●						
	Yilmaz et al.		●	●	●				●	●				●		●	●	●	●	●	
	Bacciotti et al.		●					●	●						●		●	●			●
2017	Tau & Nagai	●	●					●	●										●		
	Mirtalaie et al.		●					●	●							●		●			
	Watschke et al.		●			●			●	●					●				●	●	

3.1 When - The timing of design ideas' generation

By reviewing the papers, there is some research discussed as to when inspiration or design ideas emerge. According to Goldschmidt and Sever (2010), designers can encounter inspiration sources in an intentional, unconscious or even accidental manner. For instance, the importance of sudden inspiration or serendipitous idea to design is a fixture of design thinking and can be featured as the moment of emergence of a new idea that significantly accelerates or influences the direction of the design (Chandrasekera et al., 2013). Cross (2004) also stated that the design idea comes when hard work sessions are alternated with periods of mental relaxation away from design problems. Besides, it was reported that insightful ideas are triggered by serendipitously encountered stimuli that may occur after repeated faults have sensitized one to an unsolved problem (Smith, Linsey & Kerne, 2010). And the intuition or gut feeling, followed by analysis or synthesis, is said to play a significant role in decision-making during idea generation (Tau & Nagai, 2017). On the other hand, research indicated that student designers were able to use reflection in support of professional identity development concerning design ideas. And it also reported from the research that the more actively designers contact with outside information, the higher the possibility that they will be found by ideas or concepts, which suggests that the cognitive and psychological process could be manipulated through an actively information-seeking habit (Zhao, 2013). Similarly, there are also case studies that reveal that while searching for idea or inspiration is mostly an unconscious process, designers would benefit from making it a conscious and reflective approach (Gonçalves et al., 2014). In general, we could see that designers can extract valuable knowledge for their ideas both from random and serendipitous encounters and deliberate acquisition. But designs make ideas more reasonable and workable when analyzing holistically and consciously after initial ideas generated either with the intention or not.

3.2 What - The external sources used by designers to generate ideas

The generation of the design idea is also a process that is rooted in individual knowledge and is often considered a precedent-based type of reasoning, where knowledge is continuously transformed to produce new knowledge (Gonçalves et al., 2014). However, few designers today have the luxury of creating their own vision with no input from others (Ireland, 2003). And the design research with real people is highly needed for ideation to have accurate question, idea, prototypes and interface held up to the scrutiny of a diverse set of potential future customers so the designer could make a better choice. Therefore, different individuals do not only use their background experience and expertise, but also the research findings as well as different types of external sources in their surroundings to trigger the emergence of design ideas or influence the content of those ideas, including pictorial (Malaga, 2000; Hanington, 2003; Cai et al., 2010; Gonçalves et al., 2011), textual (Goldschmidt & Sever, 2010), verbal (Mckay, 2006), or tangible sources (Perttula & Sipila, 2007; Herring et al., 2009). Among the possible sources, the results showed that the designers give an exaggerated importance to a restricted number of sources, such as the visual representations (Malaga, 2000; Hanington, 2003; Gonçalves et al., 2011). It is partly because the visual material can indeed provide straightforward and intuitive cues that do not require translation between different perceptual modalities (Malaga, 2000), and where the form and function are in evidence (Herring et al., 2009). Visual sources are mostly used when designers are trying to understand the context of a problem or to build a reference point for how the problem has been addressed before. Comparing with the extensive use of visual stimuli, there is also research indicating the positive influence of using text sources (Goldschmidt & Sever, 2010), which seem to be regarded less important as a potential inspiration source. On the other hand, the results also showed that the external sources could be the factor of design fixation (Viswanathan & Linsey, 2013). As a major concern in design idea generation, the design fixation restricts the solution space in which designers search for their ideas. During idea generation, designers tend to fixate on examples they encounter or on their own initial ideas. For instance, physical formats were said to cause a higher magnitude of fixation than pictorial formats; however, designers also utilized physical examples producing a greater quantity of non-redundant ideas. Existing design examples and external sources have the potential to limit innovation, and it was said that building prototypes could be a solution in helping designers identify the flawed characteristics and reducing design fixation. In a word, through the review of the various external sources, designers have defined ideas generation as a process that

can integrate the use of any entity in any form that elicits that formation of creative solutions for existing problems. It is believed that designers could potentially benefit from exposure to external sources which would provide a starting point or trigger and make the idea generation more efficient. With the development of information and internet technology, a large number of product designs would be based on the deep understanding, analyzing and mining to big data in the future. However, the overwhelming amount of possible sources in the age of big data a designer could use adds to the complexity in understanding how inspiration source influences the outcome of a solution. The designers show a tendency to not fully explore a number of available resources, ultimately leading to hindrances in their creative processes. At the same time, the issue of design fixation should be paid attention to when using external sources to support ideas' generation.

3.3 Which - The tools help to generate design ideas

Idea generation plays a vital role in building a broader foundation in the design process to create novel products. An unambiguous representation of captured ideas to explicate a designer's thoughts is significant in the sharing and reuse of ideas (Vijaykumar et al., 2014). Various design studies have noted the impact of design tools on concept generation, especially the visual tools such as sketching (Chansri & Koomsap, 2014; Pan et al., 2013), collages (Saunders, 2009; Mckay, 2006), storyboard (Gonçalves et al., 2014), prototypes (Brown 2009; Pniewska et al., 2013; Gerber, 2012) and so on. It is agreed by Cross (2004) who stated that visual tools are the most important instruments to stimulate knowledge building and the enrichment of reasoning and idea forming. As an intuitive visual tool to demonstrate empirical findings or initial ideas, sketching supports a re-interpretive cycle in the individual thinking process or to enhance the access to earlier ideas (Pan et al., 2013). Besides the immediacy and flexibility of traditional sketching (Chansri & Koomsap, 2014), the emerging digital sketching tools have advantages in following ways: supported mix aspects of sketching, portable and navigable, duplicable and transferable between different tool-environments. But digital sketching has less room for imagination and creativity compared to paper sketching. Moreover, made from an assemblage of different materials (e.g. magazine clippings, handmade papers, photographs) (Saunders, 2009), collage has been used by designers to investigate feelings and emotions of users to capture or test their initial ideas. Collages support the potential end-users' expression of impression, understanding, and emotions on a product which otherwise has been inaccessible to a designer. Collages can overcome the verbal communication issues of articulation and verbosity, but also limit the problems of disclosure reluctance in order to increase the trustworthiness of the empirical finding and idea analysis (Saunders, 2009). Furthermore, as an early sample or model built to facilitate idea generation, prototypes intend to find the manifestation in its most economic form and allow the designer to physically see the concept in 3D form, and therefore an essential medium for problem-solving in design (Hallgrimsson, 2012). The rapid visualization of multiple ideas through prototypes allows the designer to reframe failure as an opportunity for re-generating (Gerber, 2012). Prototypes are also used to experiment with form and material, to explore the creative and reasonable ideas. At the same time, there is also research talking that prototypes have focused on evaluation functions rather than support of design ideas' exploration (Pniewska et al., 2013). In addition, combining aspects of imaging, graphics and scientific visualization, storyboard not only helps designers to explain the research findings and demonstrate the design ideas, but is also used to create compelling experiences that build human connections. Storyboard is significant to generate ideas in many collaborative scenarios such as when working as a team, as it allows for the most complex of ideas to be effectively conveyed inside the team or to a variety of people. In a word, the results demonstrate that the participants generate a significantly higher number of ideas and explore a larger solution space when they apply the tool during ideation process. However, the results did not detail the influence of a variety of instruments on the representation and reinterpretation of concepts and ideas through captured information or knowledge.

3.4 Who - Compare design ideas' generation among different groups

The external sources frequently used by the designers do not only rely on their individual culture, but also on their professional backgrounds. Given the keen interest in design ideas' generation among

students and professional designers, and novice and expert designers, and the emphasis have been given to these groups when doing the review (Laamanen et al, 2014). Basically, student and professional designers valued inspiration source very highly for ideas, even if they approach it in a variety of different ways. Student designers prefer to use images over objects as their inspiration source, and the latter more than text while professional designers prefer to use equally more images and objects than text as their inspiration source (Gonçalves et al., 2014). It was also found that expert and novice designers also tend to categorize information in different ways when searching inspiration sources: novice designers organize information according to more superficial characteristics and categories, whereas experienced designers are able to analyze information on the basis of many cases of solution principles they have stored in the past (Lawson, 2004; Petre, 2004). Besides, it was found in another study that novice designers are problem-based while expert ones are solution-focused when try to find design solution (Lawson, 2004). And student designers do not usually have a clear structure to guide them searching source and information, whereas expert designers are prepared to extensively analyze the problem at hand and embark on a quest for all kinds of information that might help in following the process (Cross, 2004). However, there are also some similarities between student and professional designers about design ideas' generation. A rich collection of pictorial representations could help student and expert designers when dealing with ill-defined problems. And, to some extent, both student and professional designers seem to give an excessive significance to a confined number of idea sources and approaches, when they could take advantage of a wide range of available resources. As understanding the different approaches of student and professional designers on this matter can potentially help to support them in a more efficient search, retrieval, and usage of available inspirational sources, it is imperative for student and novice designers to take the time to learn from professional and expert designers, and to build their own source database, develop their own methods and codify them into reproducible processes and artifacts (Shedroff, 2003) and to be trained with effective methods for mitigating design fixation (Viswanathan & Linsey, 2013).

4. Conclusion and implication for future research

Regarding the current state of research in design idea generation, it could be seen that varying papers focus on different sources and tools helping to generate design ideas. At first, findings indicated that seeking ideas from inspirational source becomes particularly important for industrial designers during the design process. And we could see that the designers seem to give an overstated emphasis to a restricted number of sources such as pictorial and tangible ones, while less designer prefers to use textual or verbal information as the source to generate ideas. Certainly, there is ample evidence that was compared with the discussion of advantage and disadvantage of a single source of ideation previously as indicated in Table 1, more and more studies pay attention to the relationship between various sources and their impact on design idea generation. The relationship between our society and science and technology grows increasingly complex today, to be a good inspirational source searcher, designers must have abundant knowledge, a sharp insight toward the future and are supposed to augment the search to prevent fixation when searching source during ideation. Secondly, the result also indicated that the research focuses on digital tools helping to generate ideas increased since 2013, which partly because the new technologies open the door to many new design possibilities for end-user products. It is no longer possible for any single designer to comprehend all of its facets in this new digital age. However, many designers are not familiar with the potentials of these technologies and therefore do not take advantage of them in the product development process, especially in the ideation process. To overcome barriers in the generation of new ideas caused by the limitations of conventional techniques particularly in the ideation stage, new design methods and tools are needed. Besides, from the table, we could see that other than conventional tools, there are more and more 'others' tools used by designers helping to generate ideas since 2014, including the systematic framework or methodological system to support decision making and idea generation. New design problems were emerging at a faster rate than previously in such a ubiquitous digital and information age, so ever fewer design problems could be resolved by referring back to long-established practice (Bürdek, 2005). In a highly technologically-advanced mature society, a shift in focus occurs from simplex specialized knowledge to a systematic framework that utilises sources to generate ideas.

There are imperious demands to investigate the systematic design sources and methods for ideation, to let designers, especially the novice and student designers, respond to change in environment. Thirdly, the research involve students in the last few years to a greater extent, which echoes the statement that new design sources and methods are needed for students as well as novice designers, who could be assisted to fully exploit the newly opened design potentials to overcome barriers in the ideation stage (Watschke et al., 2017). Because student and novice designers might require training for reinterpretation and extract necessary information from inspiration sources, rather than working in a poor understanding, ambiguity situation.

Moreover, it was found that most researchers had examined when and what inspirational sources designers used to support idea generation. Nevertheless, the reasons behind of the different sources used during idea generation phases are still unclear. Therefore, further research could be conducted to have a comprehensive and holistic understanding of how industrial designers utilize specific sources to generate design ideas with appropriate methods and tools, and the design thinking and strategies involved in the process. For instance, researchers could now conduct focussed methodological research to better understand how the different methods influence the results that are obtained. The more qualitative work could be used not only to understand the eligibility and limitations of each method, but also can identify which approaches work well for specific types of design problems, design domains, and types of designers. The systematic framework would provide 'cognitive shortcuts' that can help designers generate more, and more varied, candidate ideas to consider in the early phases of design. Such endeavor would offer a wide variety of resources that help designers, especially student and novice designers, reach beyond the constraints of their world-view and into a new world of choice and diversity (Ireland, 2003). Also, one limitation of our review is of insufficient conference paper included. The further suggested challenges for the field is, therefore, testing findings conducive to larger paper samples including more conference paper, which present up-to-date research and work in process than journal papers about the research topic.

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