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A STUDY ON INFLUENCE OF ANALOGY IN PRODUCT DESIGN PROCESS

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Abstract: Quality, variety and speedy response are given due importance in New Product Development (NPD) process. Inadvertently or not, analogy plays a significant role in the entire NPD process. The mechanics of analogy could be explained by the principles of cognitive psychology, and it does connect with the NPD process. An attempt is made in this paper to identify the influence of analogy to the various steps in a typical NPD process. Although all the typical NPD steps are considered, particular stress is on early stages of the NPD process till concept generation. The findings of this paper are based on the observations of the product design activities done by a group of multidisciplinary engineers in a partly controlled setting. The study as part of an ongoing research work, and attempts are made to formulate the links of Analogy to the NPD process. The findings could act as a basis to develop an analogy linked product development framework.

Keywords: *NPD, Product Design Process, Analogy*

1. Introduction

The current stage gate process adapted by the industry for product design and development is a positive mix of business and technical factors. And for the product based manufacturing industry, significant stress is still on the technical part of the product design process (Ulrich & Eppinger, 2005). Even though industry specific and company specific customizations are available for the product design process, certain steps are common in most product design processes. These common steps could be summarized as shown in Figure 1.

Oxford dictionary defines Analogy as “a comparison between one thing and another, typically for the purpose of explanation or clarification”. In ‘Analogy and relational reasoning’ (Holyoak & Morrison, 2013) states analogy as "Trying to reason and learn about a new situation (the target analog) by relating it to a more familiar situation (the source analog) that can be viewed as structurally parallel”. Holyoak also states that Human analogical reasoning is heavily dependent on working memory and other executive functions supported by the prefrontal cortex, with the frontopolar subregion being selectively activated when multiple relations must be integrated to solve a problem.

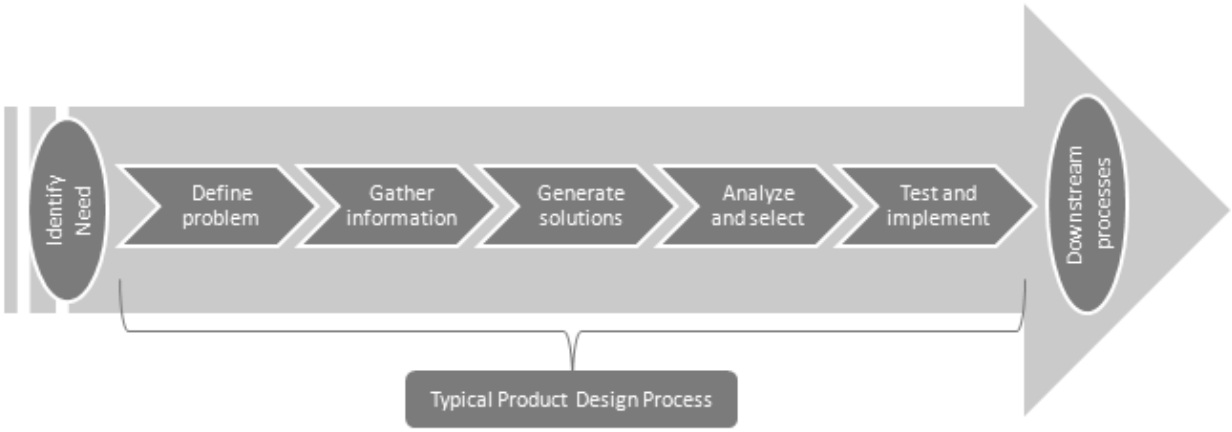


Figure 1. Typical Product Design (NPD) process

Creative professionals in general and Engineering Designers in particular uses details they were already aware of in their design, (Casakin and Goldschmidt, 1999; Christensen and Schunn, 2007; Leclercq and Heylighen, 2002). Design teams frequently use close-domain analogies in the form of references to past designs (Eckert, Stacey and Earl, 2005). Eckert, et al. found designers use references to previous designs for more than just concept generation but also in cost estimation, process planning etc.

The typical product design process has many inbuilt prompts to gather cues from analogy with everything around. And product design practictioners knowingly or unknowingly apply analogy in the product design processs. These could range from identifying similar use cases to inspired ideation. Studies in Cognitive psycology has improved the understandings of the mental models and the mechanics of analogy.

The current study adds to the existing literature on analogy and its role in the product design process on a product designer's view point. The findings of these study are based on the close observation of a guided new product development projects executed by a team of engineers. These multidisciplinary engineers are recruited to a reputed global engineering services company to play diverse product design roles across a wide range of domains including automotive, aeropace, energy, industrial machinery, medical devices etc. Our presentation of this study mostly focuses on design of simple products so that the analogy linkages in the new product development process could be depicted to a wider range of audiences including product designers, pshycologists etc.

2. The case study of marker

The Six engineers identified for the focus project group are mainly from the mechanical and aerospace backgrounds. They have little or no prior industrial experience and they have joined this induction training about 3 to 9 months after completing their engineering graduation. And as part of their induction training they have done a NPD project for three months. An introductory training was given to this group on the new product development process, before they embarked with the NPD project. The project group initially did a painstroming exersice to identify a problem area to work for. Painstorming **(**Epicenter.stanford.edu, 2014**)** is an opportunity identification technique involving observations of potential customers to identify what they do not like or what bothers them about their present products. Using weighted ranking the team then shortlisted the task to solve the issue of 'white board marker getting dried out quickly when writing continuously and needs shaking to continue writing'. The NPD project was subsequently scoped out to redesign the marker, so that the markings made are very clear even with prolonged use in any angle.

2.1. Voice of Customer

Voice of the Customer (VoC) is a term that describes our customer's feedback about their experienceswith and expectations for our products or services. Voice of the Customer is a multi-source insight platform that focuses on customer needs, expectations and product improvement. Once the Problem statement, goal statement and scope of the project are finalized the team did the Market analysis and segmentation to understand the target market in detail. Then the team collected the voice of customer (VOC). Various commonly used VOC techniques like online survey, direct and telephonic interviews, questionnaires, user observations were employed. Logical grouping of the various needs per the VOC is then done as shown in the Figure 2.

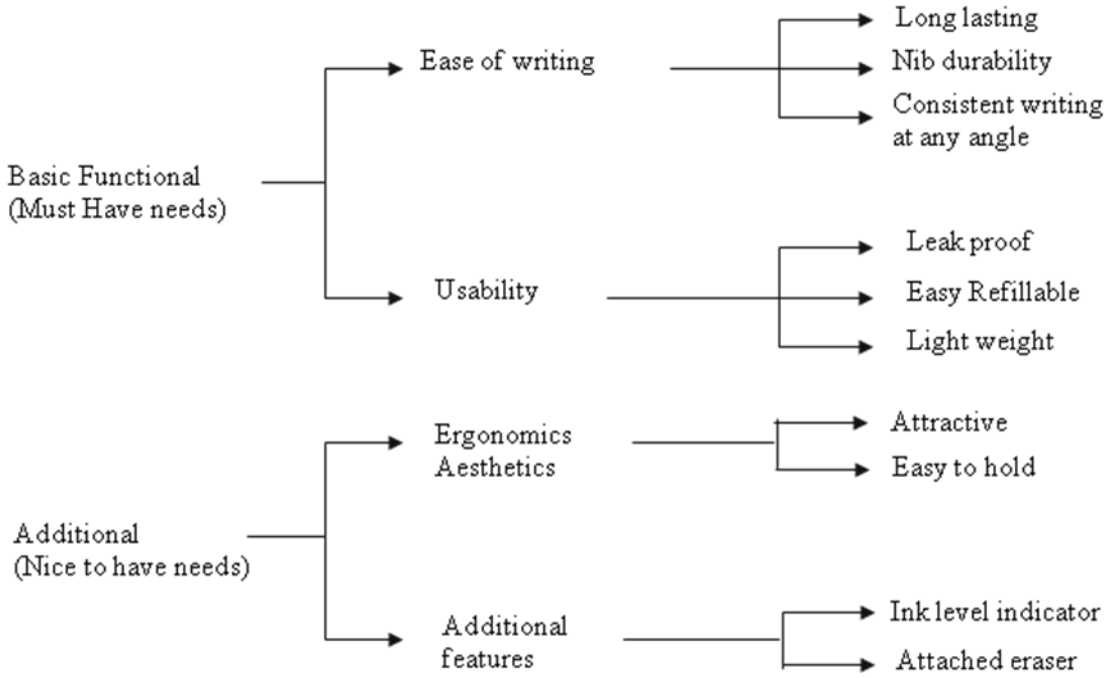


Figure 2. Key Customer needs for Multi Angled Marker

2.2. Quality function deployment (QFD)

QFD is a "method to transform user demands into design quality, to deploy the functions forming quality, and to deploy methods for achieving the design quality into subsystems and component parts, and ultimately to specific elements of the manufacturing process" (Akao, 1990). A house of quality is created and QFD is employed to analyze the inter dependence of customer requirements and the design parameters and also the relative importance of the various design parameters and the customer requirements. Target values for various design parameters were then obtained from the base of the House of Quality Matrix. Also for the next phases of NPD, QFD also enabled to infer the directions as listed below.

- Making the Marker affordable should be the topmost priority.
- Need to identify the volume of ink to be injected for consistent writing.
- Proper understanding and design of the ink flow path is required.
- Weight of the marker should not exceed the weight of available markers.
- Designing marker body with perfect sealing and provisions for additional features.
- The marker should be attractive to sustain in the market

2.3. Product Design Specifications

Preliminary Product Design Specifications (PDS) are then arrived based on the target values from the House of Quality.The PDS lists out all the parameters that should be achived in the designed product. The PDS also includes the last stage development process including packaging and testing details. The PDS acts as the road map for the further design process, and also as a checklist to compare if all the intended attributes were able to be achieved.

2.4. Functional Reasoning

Chakrabarti et. al explains that "The idea of functional reasoning in conceptual design is to reason at the functional level in order to generate solutions to specified design problem" (Chakrabarti, 1994). A functional diagram is created for the Conventional Marker and the Multi Angle Marker as illustrated in the Figure 3.

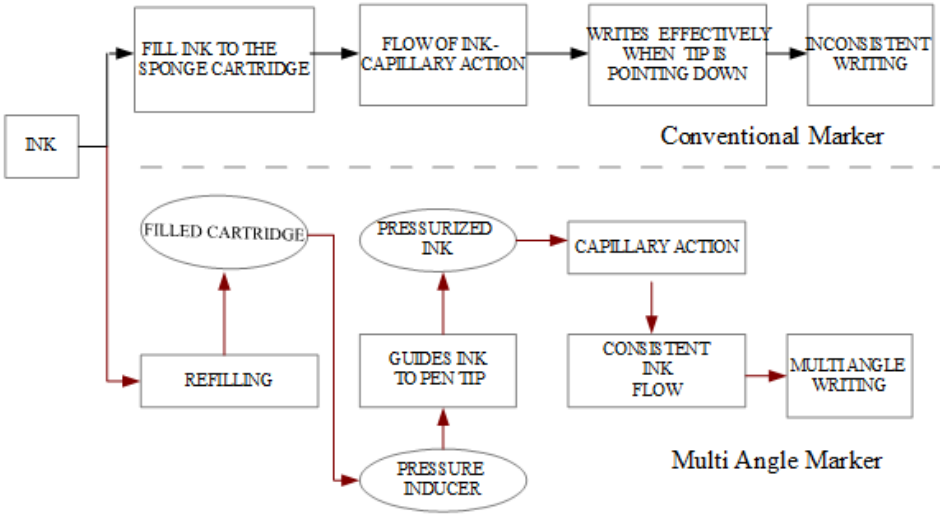


Figure 3. Functional Diagram of the existing and proposed markers

The team was then able to deduce the importance of some critical functional requirements as listed below.

- Mechanism to force ink upwards while the nib is pointing upwards.
- Consistent flow of ink.
- Easy Refilling of ink.
- Leak Proof.

Then consulting with the VOC and QFD, The team then agreed that these functional requirements are more important than the previously acknowledged design parameter listed below.

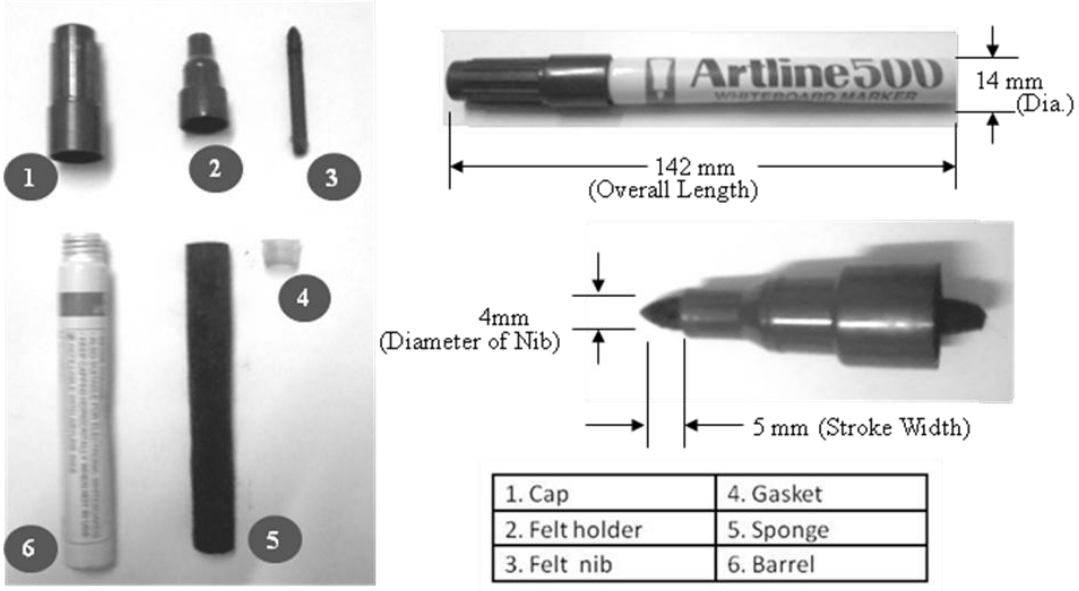
- Weight Reduction.
- Cost effectiveness.
- Attractiveness.
- Additional features.

2.5. Benchmarking and Teardown analysis.

The project team did a tear down analysis of Five white board markers products available in the market. The choice of the products was based on the ready availability of the hardware for teardown. The key results from the teardown analysis of the various products are as listed below.

The team benchmarked the dimensions of whiteboard marker to be used in the product design specifications. The team also got information on the various design parameters including the length of sponge, felt length and also on the soft plastic gasket sealing provided to prevent leakage. The various parts and the overall dimensions are illustrated in the Figure 4.

Teardown analysis of other white board markers helped the team to understand the typical construction of white board markers. Also the similarity in overall dimensions and weight was noted, which in turn helped to baseline the usability factors.
Pilot V7 and Parker ink pen: Although not whiteboard markers, teardown analysis of these pens enabled the team to understand the need to provide guides at ink casing mouth. And also on how capillarity action is achieved in these pens.



1. Cap	4. Gasket
2. Felt holder	5. Sponge
3. Felt nib	6. Barrel

Figure 1. Teardown analysis (Parts and overall dimensions)

2.6. Concept Generation

Concept development phase is relatively cheap and quick in comparison with other phases. Although creativity is very much required for all the NPD activities, Concept generation is considered to be the one that requires creativity at its abundance. As per the Oxford dictionaries creativity is 'the use of imagination or original ideas to create something useful'. Creativity was once a mystery and was considered as a special natural ability of an individual. Activities in the brain involving association, recombination, creativity and so on, are necessary to create ideas. Recent advances in cognitive psychology together with the many studies of the idea generation processes have helped to device many concept generation processes that could be imparted with training and practice. In their book "Product design and development" Ulrich and Eppinger depicts a 5-step concept generation process that focuses on understanding the problem, internal and external search, systematic exploration and constructive feedback.

There a number of creativity techniques available that augment this process and to add the creativity flavor of Concept generation. These includes Brainstorming, 6-3-5 brain writing, Biomimicry, morphological analysis, TRIZ etc. In this particular paper 'analogy' as a concept generation technique is discussed. In 'Analogical mind' (Gentner, Holyoak, & Kokinov, 2001) Gentener et. al defines analogy as reasoning and learning a new solution by relating to some familiar situation. Linsey et. al (Hey, Linsey, Agogino, & Wood, 2008) (Laux Jeff Linsey Julie, 2007), also discusses that Analogies and metaphors are usually seen as a mapping between a source and a target domain. Hey et. al (Hey, Linsey, Agogino and Wood, 2007) differenties Metaphors and analogy. Metaphors are commonly

used to map users' understanding, activities and reactions to a product and help make sense of customer needs or physical attributes from the source of inspiration. Analogy, in contrast, primarily maps the causal structure (like functional structure, geometry etc.) between the source product in one domain to the target design problem being solved.And on a designers perspective this could be illustrated as the exposure of the designer and its impact on the design decisions. Situations, People, things, places or on that case any noun could act as an source domain, and exposure to these influences the designers mind set and that inturn affects the design decisions, This could be illsutrated as in Figure 5.

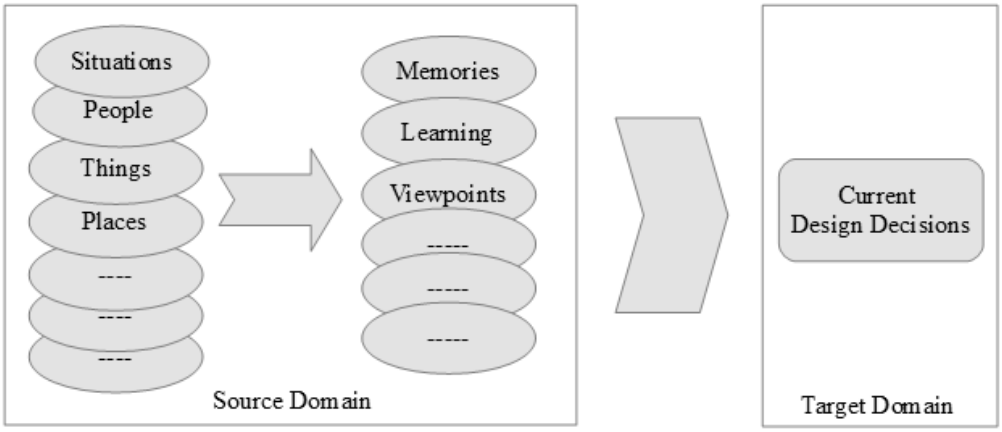


Figure 5. Source and target domain in analogous design

As part of the analogy based concept generation, The Multi Angle Marker team went about to search for possible source domains and also recall their personal exposure which could be of significance. The functional diagram which was already created was a basis for this source domain search and personal exposure recall. The team then listed down the possible sources and previous exposures that could tackle the specific functions of the product. Then the team went ahead with brainstorming and made a shortlist of these analogies. The team then shortlisted two products from source domain.

Fevi Stick Glue components

2.5 ml syringe

Cross section of mechanism of Fevi Stick Glue

Components of syringe- Plunger, Rubber seal

Figure 6. Teardown analysis

The first product is a glue stick which is a common office supply. The glue stick uses twisting actions to apply glue, and it's interesting to note that the glue stick was originally inspired from lipstick applicators ("Pritt History," 2014). The second product is the medical syringe, on which a plunger can be moved along a barrel to pull or push fluids through a orifice at the end of the barrel. A teardown study is then done on both the products. The photographs of these products from the source domain are shown in Figure 6.

The team then did the Design for Quality activities (Boundary Diagram, Interface Diagram, Parameter Diagram and DFMEA) and consequently did the detailed design, product costing etc. Finally a quick proof of concept prototype is made using syringes, glue sticks, glue dispenser, sealants and other common office supply. Some functionality testing was also done initially with water and then also with marker ink and the results were satisfactory. The prototype and the various components of the prototype are shown in the Figure 7.

Figure 7. Prototype of the multiangle marker with the various components

3. Conclusion

In this paper a typical new product development scenario is discussed, with particular emphasis on the early stages of NPD process. An attempt is made to understand the significance of analogy in the NPD process with particular emphasis to the concept generation phase. The observations from the focus group of engineers, showed that there were many analogy pointers in the product design process. Benchmarking, teardown analysis and functional analysis were few of the dominant product design steps that strongly directed towards the solution arrived by the focus group. Experienced designers often use this analogy pointers during the concept generation and other phases of product design (Eckert, Stacey and Earl, 2005). Experiencined designers were able to do so because of the exposure they gained in various domains from their experience. But novice engineers may not be able to gain from a larger exposure when compared to their experienced counterparts.

The findings from this paper directs to the usability of analogy as a efficient aid in generatingcreative concepts. Teardown analysis of items having similar functions has aided the final concept generation in the case discussed. More studies on this regard is still required to see if some forced analogy techniques embedded in the NPD process significantly impacts the productivity of typical NPD

process. More complex case studies and analysis of more multi skilled focus groups in future shall aid in refining links of analogy in product design process. This could possibly lead to techniques and frameworks in NPD process that enables the searching, identifying, sorting and grouping of source domains for the particular application in a target domain. And this analogy linked product design process could aid less experienced engineers and designers come of with more creative solutions quickly as there well experienced counterparts.

Acknowledgement

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