INTERNATIONAL DESIGN CONFERENCE - DESIGN 2014
Dubrovnik - Croatia, May 19 - 22, 2014.

STIMULATION OF CREATIVE OUTPUT BY MEANS OF THE USE OF CREATIVITY TOOLS – A CASE STUDY

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Keywords: creativity, creativity tools, problem solving, engineering design

1. Introduction

Research on creativity has thrived in many domains since the president of American Psychological Association J.P. Guildford highlighted the need for research on creativity in 1950. The advance in the status of creativity is highlighted in the call for a focus on creativity among world leading commercial enterprisers in the IBM survey, capitalizing on creativity [IBM 2010]. Creativity is often regarded as 'the ability to imagine or invent something new of value' (see, for example, [Childs et al. 2006]). Creativity is central to designers' thinking and it is of great significance in the engineering design domain. Engineering design can be defined as a systematic, intelligent process where designers generate, evaluate, and specify concepts for devices, systems, or processes whose form and function achieve clients' objectives or users' needs while satisfying a specified set of constraints [Dym et al. 2005] (see [Childs 2013]), it is an activity to establish and define solutions to problem not solved before, or new solutions to a problem which has been previously solved in a different way.
Although creativity is desirable in the engineering design field, how to enhance creativity in design remains an issue that many investigators focus on. It is generally believed that through personal assessment and deliberate intervention, in the form of training or instructions, individuals can make use of their creative styles, enhance their level of creative accomplishment and thus fully realize their creative potential [Isaksen et al. 1994]. Creativity training programs typically include the application of creativity tools such as brainstorming, Creative Problem Solving, TRIZ, and Synectics. All the creativity tools are intended to help stimulate creative thinking, which is likely to lead to novel design. They work by increasing the flow of ideas either by removing the mental blocks that inhibit creativity or widening the solution searching space [Cross 2001]. There are hundreds of creativity tools available and each has its own distinct features and mechanisms, thus it is reasonable to give thorough consideration before selecting one in a given case. It is the focus of this study to explore how to select suitable creativity tools for individuals in idea generation during engineering design problem solving.

2. Design creativity

Since 1950s, a large number of studies on creativity has blossomed and different approaches and theories have been put forward with the aim of understanding the nature of creativity. Creativity is a complicated concept where all the factors could influence the potential of creativity to occur. The focus in this study is to investigate how designers' creative thinking can be stimulated with the aid of suitable creativity tools, which will ultimately lead to creative solutions to engineering problems and this is illustrated in a practical engineering design case study.

In order to effectively employ creativity tools in engineering design, there are several variables that need to be identified beforehand. For creative ideas to occur, specific environmental conditions that support creative thinking must exist. In addition, suitable personality characteristics and abilities must be possessed by the creator, or at least can be induced and cultivated with the aid of certain tools in order to generate creative ideas and express them properly (see Figure 1). Such variables play an important role in design process and can affect the overall effectiveness of creative efforts. It is the essence of this case study to propose a theoretical framework for selecting appropriate creativity tools while in the meantime controlling and balancing other variables so as to make the optimized use of resources available and satisfy the requirements.

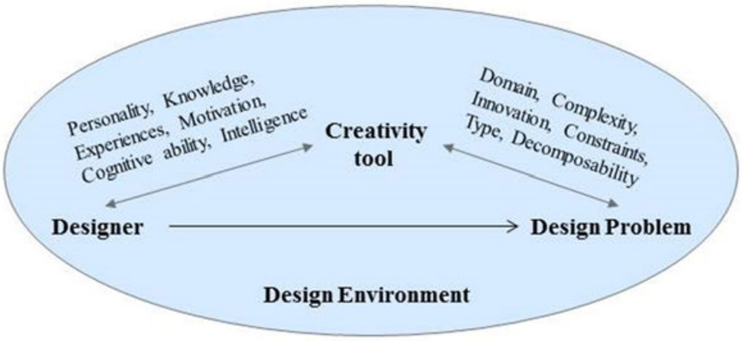

Figure 1. Creativity tool selection factors for idea generation

2.1 Creativity tool variable

The effectiveness of creativity tools is dependent upon multiple factors, such as the operational mechanisms, the application domain, the complexity and difficulty of using them, the skills or pre-knowledge required of designers, and potential risks when misused. Being flexible with different creativity tools would be of great benefits since it is unreasonable to assume that one tool would apply to all domains and all problems for all the people [Runco 2007].

Creativity tools used in idea generation can be divided into two main categories: intuitive/unstructured tools and logical/structured tools [Shah et al. 2000]. Intuitive tools, such as Brainstorming, work by stimulating the unconscious thought processes of the human mind to increase the idea flow and the outcome is rather unpredictable. On the other hand, logical and systematic tools, such as TRIZ, provide a defined direction for the concept generation process, e.g., applying a systematic approach to analyse functional requirements (see [Childs 2013]) and generate solutions based on engineering principles and/or catalogued solutions from past experience. In terms of the operational mechanisms that underlie a creativity tool to stimulate creative thinking, creativity tools fall into two categories: those that intrinsically promote idea flow and those that help remove mental blocks which inhibit creativity so as to enlarge solution search space. The former includes use of analogies and metaphors (e.g. Synectics), elements association (e.g. Morphological analysis), imagery (e.g. Mind mapping). The latter includes tactics such as suspended judgement (e.g. Brainstorming), Transformation (e.g. SCAMPER), Random input (e.g. Post-it Brainstorming). It is worth noticing that sometimes for a particular tool there is more than one operational mechanism and the interactions between these components have jointly contributed to the facilitation of creative activity.

2.2 Design problem variable

Design problems often have a goal with some constraints within which the goal must be achieved, meanwhile criteria exist by which a successful solution might be recognized [Cross 2001]. The problems that designers tackle are often regarded as ill-defined or ill-structured, engineering designers use intellectual ability to apply specific knowledge to propose solutions to such problems. The nature of design problems may influence the selection of suitable creativity tools. Eight taxonomic factors have been proposed [Frost 1994] which have an effect on the achievement of feasible design solutions. They relate to the nature and degree of conceptual difficulty which a problem or situation may present on early stage, and provide constraints on concepts or/and parameter values. Four factors are regarded as important in this case study: type of design entity ranging from a general discipline to a very specific component within a specific discipline; degree of innovation involved, from stereotype design to revolutionary design as the difficulty of design rises; the availability of potentially usable concepts identified in other domains; and complexity of design entity, referring to the number of subsystems or components that design entity contains and the complexity of configuration relating to each.

2.3 Personal variable

Increasing consensus suggests that creativity in individuals is reliant upon multiple components, which include personality factors [Feist 1998], intelligence, motivation [Maslow 1971], and knowledge (especially domain-specific knowledge), and no one component can tell the whole story. Feist [1998] concluded that in general a "creative personality" does exist, and personality traits have effects on individual behaviours and do regularly and predictably relate to creative achievement. Traditional research has argued for the "threshold theory" which states that creativity and intelligence are positively correlated up until an IQ of approximately 120, but in people with high IQs, the two constructs show little relationship [Barron 1963], although this theory has come under fire recently (see [Sligh et al. 2005]). Regarding the connection between motivation and creativity, it is generally believed that intrinsic motivation is conducive to creativity, whereas extrinsic motivation, such as expected reward and time limits, is almost always detrimental to creativity [Hennessey 2010]. Quantitative review concluded that general knowledge across domains is undoubtedly indispensable, but extensive domain-specific knowledge is even more obligated as a prerequisite for creative functioning [Weisberg 1999].

Recent evidence suggests that personality trumps intelligence as a predictor of lifetime creative achievement [Feist and Barron 2003]. The two key components of personality are its internal distinctive features which distinguish one person from another, and its relative consistency over time and situation. The internal feature conceptualized in the definition was mostly centred on the trait concept [Hampson 1988]. Investigation of the effects of personal factors imposed on the selection of creativity tools in ideation and the ultimate creative outputs is of specific interest in this study. Other factors mentioned above should be controlled to eliminate their influences on the creative efforts.

In order to make better use of designers' personal attributes to aid the problem solving, a personality survey can be carried out in advance of any creative activities to determine designers' personal traits and preferences. The Myer-Briggs Type Indicator (MBTI) is one of the most popular and widely used personality instruments [Myers and McCaulley 1985]. It identifies four cognitive functions: Sensation (S), Intuition (N), Feeling (F) and Thinking (T), as well as two attitudes that individuals orient towards the outer world, Extraverted (E) or Introverts (I), and a fourth dimension of lifestyle including Judging (J) and Perceiving (P) [Yan et al. 2013]. People use all four cognitive functions, with one function dominating the other three and it is used in a more conscious way, this one is the dominate function of one particular personality type supported by the auxiliary function, then is the tertiary one, with the last inferior function which contributes least and is the opposite of the dominate function. In this study the MBTI instrument is used to indicate designers' personality preferences and dominant traits, which will shed light on how to choose the most suitable creativity tool to use in generative activity.

2.4 Environment variable

The environment in which the designers work is also likely to affect the ideation process. Creativity tends to flourish when there are opportunities for exploration and originality is supported and valued [Amabile 1990]. Factors such as time constraints, incentives, and group influences, can influence the creative process. However, environment variables are more likely to be considered in the context of organizations and it is not the focus within this study. Those environmental variables that could affect designers should be controlled with carefulness.

3. Practical engineering design task

In this study, how to select appropriate creativity tools for engineering designers for ideation is further explored and illustrated in a practical engineering problem solving case. The selection procedure was based on an analysis of the nature of the design problem at the outset, as well as designers' characteristics by employing a personality instrument. Then two creativity tools were selected for four designers, each with between 6 and 9 years experience, to stimulate creative thinking in ideation and each was detailed described as follows. Last but not least, the engineering designer's own reflections on the utilization of specific creativity tool were discussed.

Four engineering designers formed a design team with one of them designated as the team leader. They developed their own ideas individually and met to discuss and evaluate these ideas. The deadline for this case was a few months, they followed a relatively flexible schedule to push the design process forward. The team was able to choose to generate ideas wherever they felt comfortable, either in the engineering design office or 'out and about and in their own time'. Albeit design environments do exert an influence on creative activity, this has not been isolated for consideration in this study.

3.1 Design problem

The specific design problem is a part of a joint project between Imperial College and Royal Albert Hall. It was reported that lengths of slack chain from electric chain hoists which is used to support production equipment in the Royal Albert Hall can, on occasion, spill from collection bags posing risk of significant injury to those below. It is not just a potential problem at the Hall but across many venues including live music events and festivals. In general, chain spills happens very quickly and the sound of the chain running over trusses or other resistant materials is the practical warning. Should a falling chain strike a person it could cause serious injury and even fatalities. If the chain were to strike luminaries or other production equipment, broken parts and debris could fall onto people below. The Royal Albert Hall had previously consulted industrial crane specialists for potential solutions but this did not result in any new suggestions other than considering the use of rigid collection bags as in industrial situations, which can be impractical and have other deleterious implications. Therefore they widened the consultation to explore solutions that could reduce the chain spill risks not just at the Hall but across the entertainment industry.

Four engineering design PhD students took on this case to develop solutions. In the beginning, they tried to clarify the nature of the problems and seven main potential causes and associated scenarios were identified (see Table 1). The likelihood of occurences and severity of consequences ranges from very low, low to moderate and high. This is a complex issue because several factors in this system, such as the hoist that holds the truss, the chain itself, the collection bag that hangs in the truss, as well as the interaction between those components, are all possibly responsible for the chain spill issue.

Table 1. Chain spill problem analysis summary

Issue No.	Possible causes	Chain spill scenarios	Likelihod of occurances	Severity of concequences
22	Bag affected chain falling during operation	Wrong chain falling direction	High	Moderate
2	Bag strap broke apart	Collection bag support failure	Moderate	High
17	Manual operation caused truss collision	Truss incline causing misalignment of bag and chain	Moderate	High
3	Bag surface broken	Collection bag support failure	High	Low
8	Bag strap got in the way of chain default falling route	Wrong bag initial position	High	Low
10	Wrong hoist position	Wrong bag initial position	High	Low
1	Bag-hoist connection broke aprat	Bag support failure	Low	High

3.1.1 Type of design entity

The design case is specific; the design entity involves the interactions between several components in a hoist system within the mechanical engineering discipline. The problem has been defined in detail.

3.1.2 Degree of innovation involved

The hoist system is widely used in theatre industry although the hoist models and modes of connection vary in different settings. However, the existing stereotype used in Royal Albert Hall has experienced such function failures, although infrequently, for many years, therefore some modifications are urgently needed to reduce the risks of chain spilling, the degree of innovation involved can be defined as low to medium.

3.1.3 Availability of adaptable solution concepts

The most common practice to mitigate against chain spill within the industry is to wear a safety helmet to prevent injuries during operation or making the collection bag more rigid. Such precautions do not directly solve the problem permanently; instead, they provided safety measures to reduce the chance of incident occurrences. There are many hoist systems applied in the theatre that feature different hoist model, collection bag size and shape, hoist rigging, bag-hoist connection, and chain exit position, which yield potential usable concepts that can be adapted for use in this context.

3.1.4 Complexity of design entity

With regard to the chain spill issues, a functional analysis of the whole system reveals the possibilities of malfunction of a couple of components, such as the collection bag belt broken or hoist rigging failure, as well as the interaction between them, for instance the truss tilting causing the bag misplaced which lead to the retracted chain no longer fall into the collection bag, could give rise to the incidences. The facilities at the Royal Albert Hall have, however, highlighted a few factors that were most likely to cause the issue, although there could exist dozens of possible scenarios, many of them have been ruled out due to low perceived likelihood. Based on that, the whole hoist system that design solutions are to propose for is regarded as of medium complexity.

3.2 Designers

The four design engineering designers participating in this project were three males and one female. Two of them just finished their PhD and the other two are in their second year. All of them have medium level of engineering knowledge and have design experience of between 6 and 9 years. It would be inappropriate to consider them as novice designers. They each, at the time of the study, possessed adequate engineering design knowledge but not sufficient to be considered as an expert, which is conducive to new ideas since too much knowledge and experience could result in individuals responding to a situation using well developed automatic responses that will limit originality and hence creativity [Myers and McCaulley 1992]. They were highly interested and intrinsically motivated to participate and propose some solutions. All of them took the Kersey Temperament Sorter (KTS) survey. Kelly and Jugovic's studies [2001] revealed strong positive correlations (approximately .75 correlation efficiency) between the concurrent KTS®-II and MBTI® measures of psychological types. It is suggested that KTS can be used as an alternative of the MBTI [Cheng et al. 2010].

All of the four designers had taken the KTS personality survey long before the project. They were provided the result along with a detailed readout of their indicated personality type to identify whether it closely describes the individual concerned. They took a second survey after an interval ranging from 6 months to 1 year and the result showed good test-retest reliability and consistency. Their indicated personality type is ESFP, ISFJ, INFJ and ESTJ, respectively. They have different preferences and dominant functions; therefore it is possible to proceed with creativity tool selection individually.

3.3 The selection of creativity tools

As the ideation stage is the focus in this study, therefore the process of problem finding will not be discussed in detail. Idea generation is an activity which aims to provide creative ideas as alternatives to satisfy the requirements or solve a specific problem. In order to select the most appropriate creativity tool for each designer, the applications of creativity tools, and personal preferences of designers should be primarily taken care of with modest consideration of other factors. The general selection principle and procedure is describd as follows.

Based on previous analysis, the chain spill issue can be largely defined as an engineering problem, thus creativity tools that specifically confine to other domains might not be appropriate to adopt in this case, or at least less effective than other tools during problem solving. Availability of other similar solutions in entertainment industry denotes the possibility of associating them with the current issue, or adapting them to the new situation. The complex interaction between different components of the hoist system and various constraints faced implies that when the constraints are removed and the solution searching space is widened, more solutions that are otherwise invisible are likely to emerge. This also indicates that systematic and structured creativity tools might be more preferable to handle such complex systems. In terms of the personality preferences that indicated from the personality survey, each designer demonstrates distinct inclination and dominant function, which signifies that a creativity tool must be selected with care for each individual. For instance, those who rely on instinct and imaginations may find following structures a bit disturbing, so structured tools do not seem to be an ideal option. Other personal distributes should also be considered, such as whether the designer possesses the knowledge and experience in using a specific tool, especially when the tool is highly complex and requires pre-training.

The selecting and matching procedure of appropriate creativity tools for different designers to tackle different design task is highly complex, dynamic and interactive, the most important three variables, which is personality attributes of each designer, the nature of the problem, and the application field and features of creativity tools, should be balanced and coordinated. A thorough considerations of all those viariables has led to the selection of TRIZ and SCAMPER. Screening procedure of creativity tool for each designer will be introduced as follows. It is worth noting that the suggested creativity tool for each designer in this study is one suitable example, it does not mean that it is the only suitable one.

3.3.1 TRIZ

TRIZ is a Russian acronym and can be translated as "theory of Inventive Problem Solving". Originally developed by Genrich Altshuller, TRIZ offers a practical problem solving toolkit for engineering systems. It presents a highly structured approach to problem solving based on scientific inquiry and can be used in a wide range of areas. Its 'expertise' in engineering problem solving and scientific support makes TRIZ a reasonable choice for the chain spill problem. It apprears to be a prior option for designer A and designer B considering their inclination for sensation and logic, and their previous experiences in using TRIZ. TRIZ is complex and requires high level of pre-knowledge and substantial efforts in practice, it can also be very time-consuming to learn and master its intricacies.

Designer A has involved in engineering domain for 9 years and obtained a PhD in system engineering, his expertise is TRIZ theory and application; he has studied TRIZ and its application for 5 years with a few publications on its theoretical and practical application. The personality type indicates ESFP, standing for extraversion, sensing, feeling and perceiving. The dominant function is extraverted sensing, the typical characteristics associated with this function include: preferring looking at information in terms of facts and details, focusing more on here and now rather than future possibility, feeling comfortable in areas of proven experience and taking a realistic approach. The recommended creativity tool for Designer A is 40 inventive principles of TRIZ. He can utilize his sensing function in scrutinizing the detailed information and facts of the existing hoist system and identify possible conflicts that lead to the chain spill problem. The TRIZ Contradiction Matrix will provide solution triggers from the 40 Inventive Principles which can be used to create specific solutions to the problem.

Designer B entered the engineering field 9 years ago and obtained a PhD in mechanical engineering, with expertise in creativity and innovation design. The indicated personality type is ISFJ, standing for introversion, sensing, feeling and judging. The dominant function is introverted sensing and auxiliary function is extraverted feeling. ISFJs seek to develop a realistic understanding of the world and are pragmatic in nature, they observe the problem in a subjective way, selecting and relating facts that others would not, and seeing those facts more in terms of impressions and significance than pure facts. ISFJs focus on ideas and possibilities that relate to people, which means they excel in sympathizing with other people, the recommended creativity tool for Designer B is Smart Little People of TRIZ.

Smart Little People (SLP) are imaginary tiny beings who represent the different elements of the problem that problem solvers are trying to understand and solve. By focusing on the micro level, a new perspective of the problem can be gained. This tool works as a mental trick because it is based on empathy, or creating some personal analogy with the problem. Empathy involves ‘becoming the problem’ and looking to see what can be done from its viewpoint and position [Gadd 2011]. This unique feature of SLP makes it suitable for Designer B, not only because he has used it before and can be regarded as an experienced user, but also due to his inherent inclination - his preference for feeling (F) - to relate with people. SLP can aid the problem solver to overcome psychological inertia induced by the use of specialized terminology. It is very simple, easy to learn and apply. It stimulates users' understanding of problems and helps them visualize and imagine solutions.

3.3.2 SCAMPER

The SCAMPER tool was developed from A.Osborn's checklist and introduced to education by Eberle [1997]. It uses a set of directed questions to resolve a problem, stands as a way of promoting change, suggests modification of something that already exists or improvement of the current one. SCAMPER is a mnemonic, representing Substitute, Combine, Adapt, Modify, Put to other uses, Eliminate and Reverse, it can guide you to brainstorm as many questions and answers as you can. This unstructured tool works by removing mental blocks by means of transformating, associating and promoting creative provocative stimuli, which forces the users to answer questions which they would not normally pose. It is easy to use and requires no pre-training, and can be applied in virtually all domains.
Designer C has been studying mechanical engineering for 6 years and is in his 2nd year of his PhD, with expertise in mechanical design and function analysis. The indicated personality type is INFJ, the dominant function is introverted intuition and associated characteristics include: looking at information from a global viewpoint, spotting patterns and relationships underlying his observation which lead to an understanding of key issues, his reliant upon intuition makes him perfect for the intuitive tool SCAMPER. The introverted nature enables him to use this tool more effectively alone, indulging in his inner world allowing deep thoughts and insights to gradually surface. When trying to answer the directed questions posed by SCAMPER, designer C is likely to view the chain spill problem as opportunities to design and implement creative solutions with his intuitive skills. Vivid imagination and future vision will endue him with many original, abstract and rather unpredictable ideas towards the complicated issue, which can be further elaborated later on.

Table 2. Characteristics of each designer and suggested creativity tool

	Expertise	Design experience	Personality Type	Dominant function	Personality traits	Suggested Creativity tool
Designer A	TRIZ theory and application	9 years of system engineering	ESFP	Extraverted Sensing	Realisitic, pragmatic, outgoing, flexible.	TRIZ 40 inventive principles
Designer B	Creativity, Innovation design	9 years of mechanical engineering	ISFJ	Introverted Sensing	Sympathetic, considerate, responsible, conscientious.	TRIZ Smart Little People (SLP)
Designer C	Mechanical design, Function analysis	6 years of mechanical engineering	INFJ	Introverted Intuition	Intuitive, decisive, insightful, orgniazed.	SCAMPER
Designer D	Product design, Personality traits, creativity	7 years of industrial design	ESTJ	Extraverted Thinking	Logical, objective, sensible, practical.	SCAMPER

Designer D has 7 years of user-centred industrial design experiences and 2 years of research on creativity, her expertise is product design, personality traits and creativity. The indicated personality type is ESTJ, with the dominant function being extraverted thinking. ESTJs tend to value objective criteria above personal preferences and they give more weight to logic than social considerations. Individual conflict is less likely to occur in this case due to limited human involvement, especially when she uses the tool alone. With the support from auxiliary function introverted sensing, she will collect data from the present and compare to the past experiences, so as to form goals and expectations about what to happen in the future. The auxiliary function also determines her preferences for dealing with actual facts and issues and implementing tried solutions for practical problems. The SCAMPER checklist will facilitate her in conceiving ideas from many perspectives, but her analytical and critical nature will lead to more practical ideas. The characteristics of each designer and the suggested creativitly tool are summerized in Table 2.

4. Results and discussions

After using specific creativity tools for ideation, each designer was interviewed to evaluate the effectiveness of the procedure and identify possible challenges encountered. Some of the generated soutions for the chain spill problem are shown in Figure 2. In general, the preliminary mapping of creativity tools for each designer to solve the chain spill problem was effective, which led to overall positive outcomes; the creativity tools themselves did not pose any challenges or difficulties to the designers, the ideation went smoothly and many ideas were obtained. However, each designer without exception mentioned a few barriers that prevented them from achieving better outputs.

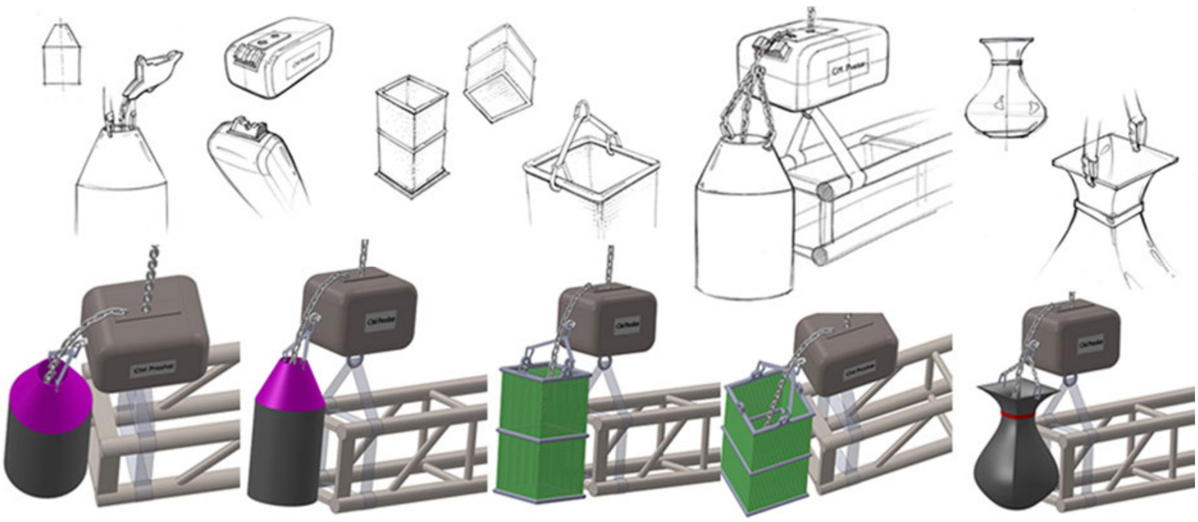

Figure 2. Some design solutions for chain spill problems

Designer A indicated that TRIZ helped the solution seeking but what concerned him most was how to identify and locate the contradiction, accurately pinpointing the essence of the problem can lead to feasible ideas with high satisfaction, however, he admitted that generalising a specific problem could be a cognitive challenging task. Deriving specific solutions from suggested general solutions also requires tremendous deduction and inference ability, as well as sufficient knowledge and experiences. Improved cognitive abilities, such as a higher level of abilities in abstraction and analogical thinking, should facilitate the problem identification and solution generation process. These findings also indicate that sufficient knowledge in the target problem domain is critical in boosting the relevant knowledge transference and adaption into the current context when using TRIZ.

SLP worked well for Designer B in identifying the problem and finding solution source. He expressed the ease of using this tool, that no significant training was needed and his previous experiences in using it made the ideation process go quickly and smoothly. He has easily incorporated himself into the problem situation and seen the problem in detail by creating a personal analogy with the problem, imagining himself as intelligent people had facilitated the breakdown of the complex problem into smaller, more digestible parts. However, the hardest part lies in transferring solutions from conceived scenario to a real-life scenario, and limited rigging knowledge is likely to impair the existing knowledge combination for breeding new solutions, the knowledge transfer could also be compromised due to the constraints from established thinking styles. Designer B's inclination for structured, pre-organized life implies his tendency to stick to old and well-established working patterns, which makes it difficult for him to think out of his area of original expertise, coping with flexibility may be not his strength.

SCAMPER stimulated designer C's creative thinking and helped him brainstorm new ideas with a wide range. The seven provocations represented different approaches to brainstorming which enabled the division of a complicated system into small and relatively simple parts where modifications could be made. The directed questions related to the problem straightforwardly; it was plain and easy to understand. However, he found that the guildlines for brainstorming may somehow limit the knowledge scope; he was expecting more unexpected and novel ideas. Last but not least, he argued that not every principle of SCAMPER was applicable to the chain spill problem; it is possible that SCAMPER works better in transforming or improving existing products or solutions.

Designer D claimed that SCAMPER served as a starting point to guide brainstorming via a checklist of directed questions, this tool was indeed very simple and needed no training. The checklist helped her start the ideation immediately and expand the solution space. She was surprised that a few novel ideas appeared although it required multiple brainpower and time to elaborate on afterwards. Although the number of creative ideas generated is relatively limited, the practicality and usefulness of ideas is already set on a certain level due to her inherent critique and objectivity. Her focus on the 'here and now' gives rise to more sensible ideas. It's safe to say that SCAMPER gave designer C many new and unexpected ideas while designer D gained more practical ideas. However, lack of experiences in solving rigging problem discouraged her from pursing more sensible solutions. It is likely that the difficulty of accessing and retrieving specific knowledge and information from long-term memory to apply in the target problem has jeopardized the optimal effectiveness of using SCAMPER. Whether SCAMPER is suitable for dealing with complicated engineering systems is up for debate. Contrary to Designer C's view, Designer D doubted its rubustness since it hardly considers the interactions among components when modifications were made and one single change could affect the whole system. Overall it's agreed that SCAMPER is a very simple but effective creativity tool to foster a large number of ideas in a short time. In this case, sufficient domain-specific knowledge and experiences in tackling hoist problem seem to be a crucial factor in determining the achievement of creative outputs.

Although each designer described distinctive even conflicting advantages and challenges when using specific creativity tools, it is reasonable to conclude that intuitive tools work well for intuitive people while logical tools take effect for sensible people. Relevant knowledge and experience is essential in using TRIZ technique. It is suitable for dealing with complicated systems which contains different subsystems or components. SCAMPER, as an unstructured tool, provides a mnemonic checklist for designers to brainstorm as a starting point. It is easy to use and can help generate a lot of ideas in a limited time, whether it is appropriate to solve complex engineering system is still up to debate.

5. Conclusions

Selecting appropriate creativity tools suited for different types of people for solving particular problem is a highly complicated issue, the creator, the design task and creativity tools are like three supporting pillars for upper idea construction, each pillar should coordinate and balance with each other as a solid base for constructing substantial outputs. Before any creativity tool selection is attempted, important attributes of each supporting pillar must be identified. The main contribution of this work lies in proposing a theoretical framework for selecting a creativity tool, it allows the development of creativity tools best suited to the personality trait and skills of the creator, and the type of design task being addressed. Although this framework was explored in this case study with four designers which seemingly bears limited generaliability, the positive outcomes increase confidence in the hypothesis concerning the need to carefully match creativity tools according to application and traits. There is no currently known way to guarantee the optimized arrangement of the most suitable creativity tool for each individual for specific design task, but more empirical studies in practice, such as conducting comparsion experiments to evaluate the creative outputs when different designers with different personality traits using the same creativity tools, or to investigate how the designers can ultilize the same creativity tools to deal with varying design tasks, should provide new insights on the matching procedure and the generative power of creativity tools.

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