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TOWARDS A MEASURE FOR ASSESSING CREATIVE INFLUENCES OF A CREATIVITY TECHNIQUE

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Abstract

Product innovation is central to the success of manufacturing industry. Creativity, the process by which novel and interesting ideas are created, plays a central role in innovation. One goal of design research is to understand the influences on and processes of design creativity, so that these can be inculcated and practiced by product developers to gain competitive advantage. Also, there is a variety of creativity techniques, but apart from few studies undertaken for a few well-known techniques, most have only anecdotal evidence of their worth and their exact influences on the creative problem solving process. In this paper, we do a survey of various theories of creativity and design problem solving in order to identify the main problem solving tasks and the main influences on creativity in the context of product development. Based on these, we develop a measure with which to assess the relevance and worth of a creativity technique, so that it can be used at appropriate stages of product development, and in appropriate combinations with other techniques in order to deliver the necessary outputs.

Keywords: Creativity technique; design innovation; influence measures

1 Introduction

Product innovation is central to the success of manufacturing industry. Creativity, the process by which novel and interesting ideas are created, plays a central role in innovation. One goal of design research is to understand the influences on and processes of design creativity, so that these can be inculcated and practiced by product developers to gain competitive advantage. Also, there is a variety of creativity techniques, but apart from few studies undertaken for a few well-known techniques such as Synectics [1], most have only anecdotal evidence of their worth and their exact influences on the creative problem solving process.

In this paper, we do a survey of various theories of individual and team creativity and design problem solving in order to identify (1) the main influences on creativity in the context of product development, and (2) the basic problem solving tasks. Based on these, we develop a matrix with which to assess the relevance and worth of a creativity technique, so that it can be used at appropriate stages of product development, and in appropriate combinations with other techniques in order to deliver the necessary outputs.

2 Research Method

The research method consists of the following steps:

- Review major theories and models of creativity, including Generativity theory [2], visual thinking [3], theories based on Preconscious mind [1], and hemispherical theories of creativity [3]. Identify common creativity enhancing/inhibiting factors from these.
- Review major theories and models of design problem solving [e.g., 4, 5], including systematic methodologies. Identify major problem solving activities and links between them.
- Based on the above two findings, develop a framework for creative design problem solving, and a measure for positioning a creativity technique and estimating its potential influences on creative problem solving.
- Test the measure by analysing the results of applying various existing creativity techniques on problem solving and correlating these to the estimations provided by the measure.

3 Major creative influences and problem solving tasks

Analysis of major theories of creativity led to the following being identified as some of the major influences on creativity:

- Creativity requires knowledge: the wider the variety of the domains and the broader the base of this knowledge, the better it is. For instance, Generativity theory [2] says that multiple behaviours must exist in the brain for one to be creative; Theory of visual thinking [3] states that information must be available to one for being creative. This is because creativity is seen as the ability to process knowledge in unusual ways, and without knowledge being there, its processing is not possible. Theory of the 'preconscious' [1] maintains that the 'unconscious' mind stores all experiences, while the 'conscious' mind has only access to knowledge that is known and readily available. The uncontrollable 'preconscious' mind links these two, delving into the 'unconscious' to solve problems. This means that the 'unconscious' mind provides a large and varied base of knowledge that is processed by the 'preconscious', pointing to the central importance of knowledge in creativity.
- Creativity requires knowledge to be processed flexibly: McKim [3], for instance, states that flexibility in processing of information is a must for creativity. Flexibility can be in terms of moving between levels (e.g., conscious, preconscious, etc), between operations (e.g., abstraction, rotation, matching, etc) or between vehicles (e.g., verbal/temporal, visual/spatial, etc). Analogical reasoning plays a central role in creative thinking, and flexible use of knowledge aids this [6, 7]. The right/left brain experiments quoted in [3] suggest the largely complementary roles played by the two brain hemispheres: the right brain with visual, spatial, non-rational behaviour, and the left brain with verbal, temporal, rational behaviour. The two hemispheres are connected by a large number of connections, and together provide the ability to develop unusual and interesting ideas, which can be simultaneously true only if both rational and non-rational faculties work together, which in turn indicates the necessity of flexibility in knowledge processing. TRIZ theory [8] suggests that 'psychological inertia' plays a central block to creative thinking, by making mind proceed in familiar directions within known areas of knowledge. This too seems to be strongly linked to inflexible processing of a relatively small domain of knowledge, which require, for avoidance, both a wider base of knowledge and its flexible processing.

- Creativity requires strong motivation (interest and challenge): Generativity theory [2] maintains that multiple behaviours must compete in the brain for it to create diverse ideas, and this is enhanced by challenge and interest. For example, failure plays a central role in providing challenge, as does keen, long standing interest in the problem. This is particularly important since ‘preconscious’ mind plays a central role in creative problem solving [1], and strong impact (interest or challenge) is more likely to engage the apparently uncontrollable ‘preconscious’ into problem solving. The visual thinking theory [3] also takes ‘challenge’ as a central ingredient of creative thinking.

Analysis of literature in design problem solving [4, 5, 9] led to the identification of the following primary problem solving activities:

- Problem understanding: this consists of secondary activities such as identification, analysis and choice of problems and task proposals. Problem understanding is carried out usually at the earlier portions of the design process, and is typified by generation of solution proposals that are not further developed, but are created in order to better understand the problem.
- Problem Solving: this consists of secondary activities such as generation, evaluation and selection of solution proposals. Problem solving is usually carried out at the later portion of the design process, and it typified by solutions that are generated and seriously considered for further development.

4 A measure for assessing creative effects of a method

Combination of the two sets of findings (creative influences, and problem solving tasks in product development) in section 3 leads to a framework for creative problem solving, which is a knowledge processing cycle consisting of generation, visualization and evaluation of tasks and solutions that requires motivated, flexible processing of knowledge for creative outputs.

Using this as the basis, a creative problem-solving matrix is developed with factors influencing creativity (i.e., knowledge, flexible processing and motivation) placed in rows, and problem solving activities (identification/generation, analysis/evaluation, and selection of tasks and solutions) placed in columns, with intersections between them to be filled in as an estimate of the extent to which the creativity influence necessary (from the row) for the problem solving activity (from the column) is provided or supported by the method under evaluation.

	Problem understanding			Problem solving		
	Problem identification	Problem analysis	Problem choice	Solution generation	Solution visualisation	Solution evaluation
Provides knowledge						
Supports flexible processing						
Provides motivation						

Figure 1 Creative problem-solving matrix

Here, *knowledge* is understood as factual or domain knowledge that is required for carrying out an activity. For example, a technique may list out the usual tasks involved in a product development problem, or a checklist of types of tasks involved in typical problems. Similarly, a method that uses a compendium of mechanisms will provide knowledge of mechanisms that can be used for solution generation, and therefore will provide knowledge for solution generation.

Flexible processing of knowledge is understood here as some steps or procedural knowledge that supports free associations between parts of this knowledge so that fresh, alternative ways of doing, or alternative outcomes of an activity can be found. For instance, a flexible problem/task analysis will lead to several complimentary or alternative analyses of the task, so that a problem/task may be viewed and reviewed in several ways.

Providing motivation is taken here as providing inputs that motivate a designer to work harder on the problem. This can be in terms of a designer getting more stimuli by means of interesting triggers, or more challenges by means of, say, more failures. For instance, brainstorming continues to produce new and crazy ideas, thereby inspiring a designer to think up newer ideas.

5 Evaluation

In order to evaluate the efficacy of the measure for positioning and evaluating creative influences of a method, the following approach was used:

- Four design methods were chosen as test cases for evaluation. These were: Ideal design method from TRIZ [8], Innovation Situation Questionnaire (ISQ), also from TRIZ [8], Function analysis method [10], and Brainstorming [5]. For more details about the methods, see [5, 8, 10]. Function analysis and innovation situation questionnaire were chosen as they are generally believed to be aids for problem understanding; brainstorming and ideal design method were chosen since they both are intended to be aids for solution generation. We originally thought we could contrast them to identify their relative effectiveness in intended activities, and find scope for how they could be blended into more powerful systems, for both individual activities and the overall conceptual design process.
- These methods were estimated for their potential impact by filling in the cells in the creative problem-solving matrix. The result of the estimation is shown in Table 1.

Table 1 Experiments conducted

Brain storming	**Ideal Design**	**ISQ**	**Function analysis**
Team 1 problem 1	Team 1 problem 1	Team 1 problem 2	Team 1 problem 2
Team 2 problem 2	Team 2 problem 2	Team 2 problem 1	Team 2 problem 1

- Two teams (Team 1 and 2) of three designers each, pursuing Masters in Design, were asked, in four separate exercises in contrived settings, to carry out conceptual design for two given problems (problem 1 and 2), using a specified method in each exercise, and the proceedings of their design process was analysed using a vide-protocol study, see table 1. A description of the method was given beforehand to each team in order to ensure they followed the same specified method, rather than a variant of this with which they were more familiar.

- Results from step 3 were compared with estimations from step 2 to evaluate the measure. This required the observations to ideally reveal the extent to which a given method provided knowledge for a given activity, supported flexible processing for an activity, or provided motivation for that activity. However, operationalising these influences in terms of observations in the experiments was not possible. Consequently, it was assumed that if a method were to provide substantial support to a particular activity, more time than usual would be spent on that activity while using that method, and therefore the percentage of time spent in that activity compared to when no intervention is used should act as an indicator of how strong the likely effects of the influences on the activity would be.

5.2.1 Estimation of effects of a method

The results of estimation of the methods using the matrix are given in tables 2-5. A single star (*) stands for a minor effect to the activity-influence pair where it is placed, while a double star (**) stands for a major effect.

The assessment for brainstorming method is taken as an example of how estimation of potential creative effects is carried out for each method. The reasons for the assessment of brainstorming method (see table 3) are as follows:

- In the brainstorming method, one step is to have a preparatory meeting with the participants, right before the actual brainstorming session, where rules are explained, problem, if necessary, is redefined, and a short, stimulating 'training' brainstorming exercise unrelated to the problem is held. Since the participants are encouraged to think about re-defining the problem if necessary, it is taken as a minor motivation for identification, analysis and choice of problem (minor effect on each).
- The 'training' brainstorming session provides stimulation, and hence motivation for the 'actual' brainstorming session. Also, solutions generated during brainstorming are displayed to all participants, providing motivation. Along with this, the second step - 'actual' brainstorming session - explicitly asks them to generate ideas, providing further motivation. Hence, it is estimated that the method provides major motivation for idea generation. Since there are well-defined but loosely connected steps in the brainstorming approach, with rules that encourage free associations, combination and free-wheeling, it is assumed that the method provides major support for flexible processing of knowledge at solution generation stages. Since ideas generated by others are displayed for all to use in further generation of ideas, there is some provision for domain knowledge in the method. It is estimated, therefore, that the method has a minor effect in providing knowledge for solution generation.
- After the brainstorming step is completed, participants are asked to delete 'silly' ideas first, then cluster the remaining ideas into groups of similar ideas, and then elaborate and evaluate the ideas. Since there are explicit instructions for deletion, clustering and evaluation of ideas, it is estimated that this step provides major support for processing of knowledge during solution evaluation, and since participants are encouraged to evaluate ideas, it provides a minor motivation for evaluation.

The overall assessment of creative effects of these techniques is as follows:

- Ideal design method: should mainly support problem identification and analysis and solution generation, with minor support for problem choice and solution evaluation.
- Brainstorming method: should mainly support solution generation and evaluation with minor support for problem identification, analysis and choice.
- Function analysis method: should mainly support problem identification and analysis, with minor support for problem choice, solution generation and evaluation.
- ISQ method: should mainly support problem identification, analysis and solution generation, with minor influence on problem choice and solution evaluation.

Table 2 Assessment of creative influences of the Ideal Design method

	Problem identification	Problem analysis	Problem choice	Solution generation	Solution evaluation	Solution selection
Provides knowledge						
flexible processing	**	**	*	**	*	
Provides motivation	*	*	*	*		

Table 3 Assessment of creative influences of the Brainstorming method

	Problem identification	Problem analysis	Problem choice	Solution generation	Solution evaluation	Solution selection
Provides knowledge				*		
flexible processing				**	**	
Provides motivation	*	*	*	*	*	

Table 4 Assessment of creative influences of the Function Analysis method

	Problem identification	Problem analysis	Problem choice	Solution generation	Solution evaluation	Solution selection
Provides knowledge	*					
flexible processing	**	**	*	*	*	
Provides motivation	*	*	*	*	*	

Table 5 Assessment of creative influences of the ISQ method

	Problem identification	Problem analysis	Problem choice	Solution generation	Solution evaluation	Solution selection
Provides knowledge		*		*		
flexible processing	**	**	*	**	*	
Provides motivation	*	*	*	**	*	

On the whole, it appears that the influences of function analysis and brainstorming seem to be mainly in problem understanding and problem solving respectively, while that of ISQ and ideal design method are more balanced.

5.2.2 Comparison with results from experiments

Video tapes of the experiments are transcribed into written protocols, coded using two primary categories (problem understanding, acronymed PU and problem solving acronymed PS) and six secondary categories mentioned in Section 3. Of these, three categories denote problem-understanding activities: problem identification (PI), problem analysis (PA) and problem choice (PC), while the other three denote problem solving activities: solution generation (SG), solution evaluation (SE) and solution selection (SS). All categories are taken from [4]; the team protocol data from the same work is used as reference for this analysis.

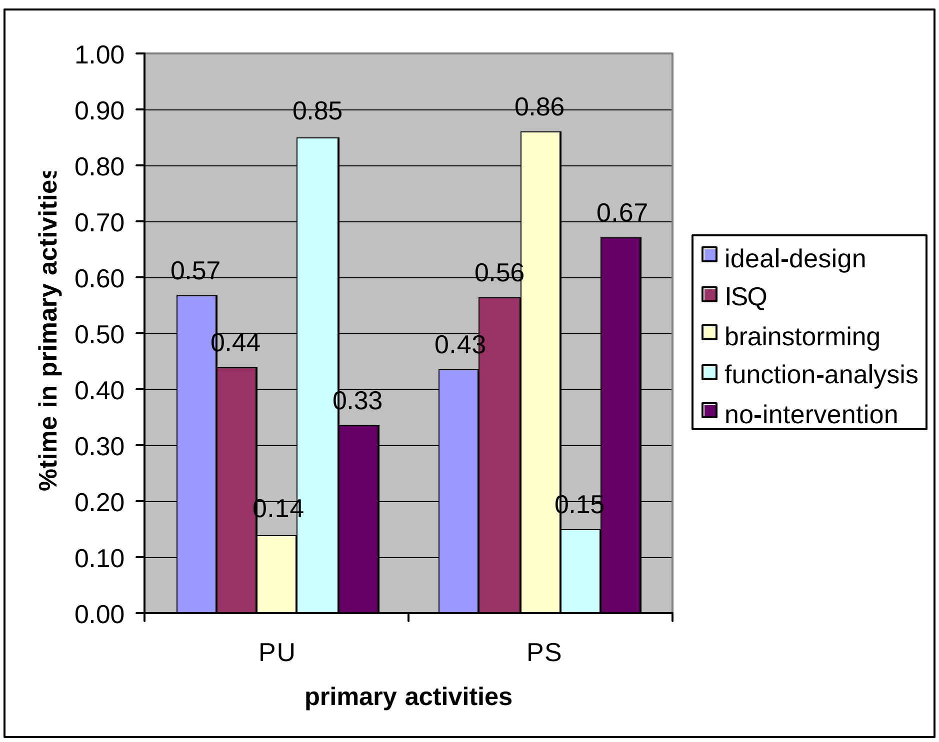

Figure 2 Percentage of time spent in primary activities

Figure 2 shows the average percentage of the total design time spent, in the design processes using various methods, within the two primary activities. The average percentage of design time for a given activity (such as problem understanding) while using a given method (or otherwise) is calculated by dividing the aggregate of the amount of time spent in the given activity by the design teams in their design processes using that method by the aggregate of the total amount of time spent by the teams in those design processes. The average percentage of time spent in these activities, for designing without intervention, is also shown. It can be seen that, while function analysis and brainstorming spend over 85% of the time in problem understanding and problem solving respectively, the other two methods split their time almost evenly between the two activities, although tipped a little in opposite directions. If this is noted relative to the figures pertaining to the design process without intervention, where about one third of the time is spent in PU and the rest in PS, all methods but brainstorming seems to encourage PU more than PS, as generally expected from Tables 2-5.

Figure 3 provides a more detailed picture of the distribution of time in these activities, in terms of the percentage of time spent in the six secondary activities mentioned. Taking the non-intervention case as a reference again, the following trends can be noticed:

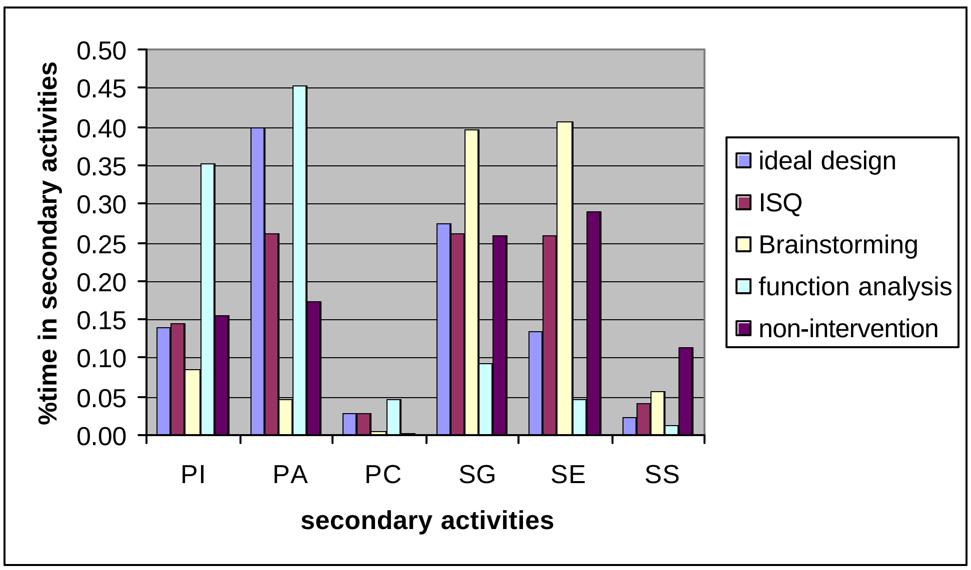

Figure 3 Percentage of time spent in secondary activities

- Ideal design: Within PU, more time is spent on problem analysis and problem choice, while percentage of time for problem identification remains about the same. This is interpreted as all three activities being encouraged by the method. Within PS, solution generation time remains the same even though percentage of time spent on problem solving goes down. This is interpreted as solution generation being strongly encouraged by the method.
- Brainstorming: Within PU, average percentage of time for problem choice goes up. This is interpreted as the activity being strongly encouraged by the method. Also, the relative percentage of time for problem identification among the three PU activities go up relative to that in the non-intervention case, and is interpreted as problem identification being somewhat encouraged. In PS, both solution generation and evaluations are strongly encouraged.

- Function analysis method: Within PU, percentage of time for all three activities goes up. This is interpreted as all activities in PU being strongly encouraged. Within PS, percentage of time for all activities is reduced, but among them, solution generation is relatively encouraged.
- ISQ: Within PU, percentage of time for problem identification remains about the same while that for the other two activities go up, which means all three are strongly encouraged. Within PS, percentage of time in solution generation remains about the same while that in solution evaluation is slightly decreased, which, given that overall time spent in problem solving goes down substantially, means that solution generation is actually strongly encouraged (indicated using **) while solution evaluation is somewhat encouraged (indicated using *).

Table 6 Comparison of estimates with experimental results

	Problem identification		Problem analysis		Problem choice		Solution generation		Solution evaluation		Solution selection	
	Est	Res	Est	Res	Est	Res	Est	Res	Est	Res	Est	Res
Ideal design	**	**	**	**	*	**	**	**	*			
Brain storming	*	*	*		*	**	**	**	**	**		**
Function analysis	**	**	**	**	*	**	*	*	*			
ISQ	**	**	**	**	*	**	**	**	*	*		

Comparison of the experimental results (Table 6) with the estimates indicate that for 19 out of 24 cases (80% of the cases) above, there were similar trends in both estimation and experimental results. Although we have no benchmark to judge whether this is a good result, it appears to be in satisfactory agreement with observation and provides some corroboration of the measure.

6 Discussion, conclusions and further work

Some of the key findings of the work described are:

- Some of the central influences on creativity are: knowledge, flexible processing of knowledge, and motivation.
- Some of the basic problem-solving activities are identification, evaluation and selection of problems and tasks, and solution proposals.
- A framework combining these provide a potentially powerful way of analysing various design creativity techniques to identify their context and worth.
- This should help in finding creative ways of combining these methods to develop more powerful, hybrid techniques that leverage the advantages of the individual techniques.

One of the prime motivations of this work is that evaluation of the various creativity methods and techniques using the proposed measure should make it easier to identify the relevance and usefulness of the techniques in the context of creative problem solving. This has been partially achieved in that, we can comment on as to which problem-solving activities are supported (or otherwise) by use of each technique. For instance, the results make it clear that (1) function analysis is primarily a technique for problem understanding, while brainstorming is a problem solving technique, (2) they play complimentary roles in problem solving, and (3) that they could be profitably combined into more powerful hybrid techniques, such as the use of brainstorming for generating sub-proposals at the end of the function analysis method. However, use of the proposed matrix also makes it clear that neither of the techniques appears to support solution selection, and that this is necessary for effective and complete problem solving. It is also revealing to find that while the ideal design approach is proposed as a problem solving technique complementary to ISQ which is supposed to be a data collection technique in TRIZ [8], they are in fact quite similar in output, and therefore not complementary at all, and that either would form a relatively self-contained creative problem solving method if supplemented by some methods that support solution evaluation and selection. However, while the method of evaluation helps identify the activities that are (not) supported by a given technique, it is not sufficiently advanced to identify as to what creative influence was due (or otherwise) for the effect. Further work is underway to develop the method of evaluation further along this direction, and further evaluate these methods and others, so that both validity of the approach and possibilities for developing effective hybrid techniques could be enhanced.

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