

# *Understanding design ideation mechanisms through multilevel aligned empirical studies*

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*The overall objectives of the study are to identify key components of ideation methods and develop effectiveness metrics. This paper presents experimental results conducted on six ideation components (Provocative Stimuli, Suspend Judgment, Flexible Representation, Frame of Reference Shifting, Incubation, and Example Exposure). These experiments were conducted simultaneously at the Design (engineering) and Lab (cognitive psychology) levels following an experimental procedure previously developed to align these two levels of experiments. Results show the effectiveness of the ideation components in terms of effectiveness metrics and also the extent of alignment of the results from these two levels. Understanding of ideation components has been gained (main effects ease of manipulation and interactions).*

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*Keywords: design ideation, creativity, design cognition, engineering design*

The overall objectives of the study are to gain an insight into cognitive mechanisms in design ideation by identifying key components of ideation methods and developing effectiveness metrics. The first step is to understand the effectiveness of such ideation components through empirical evaluation. Based on past experience (Shah, Kulkarni, & Vargas-Hernandez, 2000; Shah, Smith, Vargas-Hernandez, Gerkens, & Wulan, 2003) conducting experiments on ideation methods as a whole had major limitations: (1) inability to discriminate between necessary and superfluous components, (2) prohibitive number of experiments required (i.e. one for each method or variation), (3) inability to extrapolate experimental results to different environments, design problems, and human variables, and (4) poor understanding of the causes and effects of ideation. Shah, M.S. Smith, et al. (2003) introduced an experimental methodology to overcome these limitations. Design researchers at Arizona State University (ASU) and cognitive researchers at Texas A&M (TAMU) developed an ‘aligned’ experimental approach that

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[www.elsevier.com/locate/destud](http://www.elsevier.com/locate/destud)  
0142-694X \$ - see front matter *Design Studies* 31 (2010) 382–410  
doi:10.1016/j.destud.2010.04.001  
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combined the complementary strengths of highly controlled (cognitive) Lab experiments and available atomic process models from cognitive science with design (engineering) experiments from design research. Simultaneous experiments were conducted at both Design and Lab levels on ideation components instead of ideation methods as a whole. Ideation components are defined as mechanisms believed to intrinsically promote ideation or to help designers overcome mental blocks.

This paper presents the main effects of the ideation components and some of their interactions. These results are shown in the Experimental Results section. Since the experiments were conducted at the ASU-Design and TAMU-Lab experimental levels, these results (i.e. main effects and interaction effects) were compared to evaluate the level of alignment. Higher-level observations were made not only from the experimental results but also from the experimental procedure.

## *1 Literature review*

A comprehensive classification of ideation methods developed in the last four decades can be found in Shah (1998), Shah et al. (2000), Kulkarni (1998), and VanGundy (1988). These methods can be classified into intuitive and logical methods. Intuitive methods attempt to overcome mental blocks (e.g. Brainstorming and C-Sketch) while logical methods make use of charts, databases, patent searches, physical principles, etc. (e.g. morphological charts and TRIZ). Intuitive and logical methods are important for the generation of ideas, but intuitive methods are typically the least understood and the ones with higher chances of producing novel ideas since logical methods clearly define the solution space while intuitive methods attempt to expand this space. Intuitive methods are the focus of this research. Ideation methods provide a prescription (i.e. a normative procedure) on how to overcome certain blocks to creativity, such as premature judgment. The empirical evidence of their effectiveness is frail; research studies like this one are needed.

### *1.1 Ideation components and effectiveness metrics*

Kulkarni and Shah observed that many intuitive methods had many common elements, which they termed ideation components. Ideation components (Kulkarni, 2000; Kulkarni & Shah, 1999) are defined as cognitive mechanisms believed to intrinsically promote ideation or to help designers overcome mental blocks. Evaluating specific ideation methods in their entirety (known as the Direct Method) is complicated, the reason for this being that many components are at play simultaneously. The alternative was to identify components of ideation methods and test them individually (Component Based Method). The effectiveness of specific ideation methods could then be predicted by the components present in the method. Another advantage is that ideation components are commonly accepted and understood in engineering design research and cognitive psychology; this allows the possibility of connecting

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