Enhancing novelty with knowledge-based support for Biologically-Inspired Design

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With a two-decade consistent research interest for Systematic Biologically-Inspired Design, a number of methods and tools to support bio-ideation have been proposed. However, objective quantification of the effects these aids have on the design outcomes is rare. This contribution presents an impact analysis of the most popular knowledge-based tool, AskNature, in the form of an outcome-based study. The results consistently support a common claim used in favour of bio-inspired design, i.e. the expectation of identifying more out-of-the-box solutions. Furthermore, to further facilitate biological solution analysis and cross-domain knowledge transfer, an adaptation to AskNature's stimuli format — i.e. adding a graphical illustration of the biological solution principle — is validated to further boost novelty.

Keywords: conceptual design, creative design, design method(s), evaluation, Biologically-Inspired Design

Creative problem solving is a key task for companies pursuing inventions that may grow into successful innovations. One strategy for solving new problems is learning from previously solved analogous problems. In Design-by-Analogy (DbA) a solution principle behind an already solved problem is transferred to solve a new problem. For example, when looking for new ways to unfold a tent, products with similar functionality, like for instance umbrellas, can be sources of inspiration and knowledge transfer. Biologically-Inspired Design (BID) is a specific type of between domain DbA where inspiration is taken from the natural world (source domain) to solve technical problems or challenges (target domain). Three frequently used arguments for looking at nature for inspiration are (1) the proven performance of biological systems, (2) the potential for sustainable products and (3) the potential for finding out-of-the-box solutions. The first, proven performance of biological systems, logically follows from the overwhelming evidence supporting evolution, i.e. the change in inherited characteristics of biological populations over successive generations, a continuous repetition of a non-random selection mechanism (survival of the fittest) applied to traits subject to random variation. The products of these continuous improvement iterations — solution principles of biological systems —

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offer attractive starting points compared to an empty drawing board. The second and third arguments, however, are currently not backed by adequate empirical evidence. Although it seems logical that a natural world, where problems are solved with renewable material and energy resources while avoiding the creation of ever-growing waste piles, has the potential for inspiring (more) sustainable technical solutions, systematic evidence quantifying this popular advantage currently is missing. The third argument, enhanced potential for finding out-of-the-box solutions, is motivated by the fact that biology is a largely untapped knowledge domain and that bio-inspired design uses far analogies with little common ground in superficial properties. Although previous studies measured the impact of following a course in bio-inspired design (Nelson, Wilson, & Yen, 2009), of presenting a single biological solution versus a technical solution (Wilson, Rosen, Nelson, & Yen, 2010) and of directing students to think of nature for problem solving Glier, Tsenn, and McAdams (2012), currently no knowledge-based bio-ideation tool has been quantitatively evaluated. Therefore this contribution measures the effect the use of a knowledge-based BID tool has on the generated design concepts. For this purpose the impact of the most commonly used tool, AskNature, is quantified with an hereto designed outcome-based experiment. Furthermore, a potential improvement of AskNature's standard stimuli representation is investigated.

The next section provides the reader with the necessary background in Systematic Biologically-Inspired Design (SBID), outcome-based validation metrics and of the state-of-the-art in BID outcome-based experiments. Section 2 details the experiment's hypotheses, Section 3 the experiment setup and Section 4 the results. Finally the discussion of the results and general conclusion are respectively presented in Sections 5 and 6.

1 Background

First, existing bio-ideation tools are listed and the choice of AskNature is motivated in Section 1.1. Next, the four typical metrics used to quantify an ideation tool's performance are detailed in Section 1.2. These are quantity, variety, novelty and quality (Shah, Smith, & Vargas-Hernandez, 2003). Finally, Section 1.3, discusses findings from previous BID experiments and extracts opportunities for improvement of the proposed experimental design.

1.1 BID supporting tools

The last two decades a research community grew that aims at developing methods and tools to support the Systematic BID process. These approaches include keyword-based search methods (Kaiser, Farzaneh, & Lindemann, 2014; Lenau, Dentel, Ingvarsdóttir, & Gudlaugsson, 2010; Shu, 2010), approaches supporting on the classification of biological strategies (Deldin & Schuknecht, 2014; Vincent, Bogatyreva, Bogatyrev, Bowyer, & Pahl, 2006),