Collaborative problem–solution co-evolution in creative design

Stefan Wiltschnig, Bo T. Christensen, Department of Marketing, Copenhagen Business School, DK-2000 Frederiksberg C, Denmark
Linden J. Ball, School of Psychology, University of Central Lancashire, Preston, PR1 2HE, UK

Creative design concepts are often viewed as developing iteratively, with the design problem and solutions 'co-evolving' in a mutually adaptive manner. We report a study examining whether the co-evolution concept captures the creativity arising in collaborative, team-based design practice. The analysis revealed that co-evolution episodes occurred regularly and embodied various directional transitions between problem and solution spaces. Moreover, the team leader often initiated this co-evolution. Co-evolution episodes linked with other creative activities such as analogising and mental simulation and there was a clear association between co-evolution and expressions of epistemic uncertainty, suggesting that designers were dealing with considerable complexity and ambiguity. Our findings support the view that co-evolution is the 'engine' of creativity in collaborative design.

Keywords: problem–solution co-evolution, creative design, collaborative design, design cognition

Efforts to advance a scientific understanding of the design process have given rise to many important insights over the past four decades, with a large number of these insights being reported in the pages of this journal. Arguably one of the most noteworthy ideas to emerge in recent years is that creative design concepts can be viewed as being developed through an iterative process, whereby the design problem and potential solutions 'co-evolve' over time, with the designer exploring two conceptual spaces, a 'problem space' and a 'solution space', with each space informing the other. According to this iterative, co-evolution view of design, not only do potential design solutions receive consideration in the context of the requirements that define the problem, but such requirements can also themselves be adapted in the light of novel solution attempts. As such, design problems are not fixed but are mutable, unlike the view of design espoused in the traditional 'problem solving' model (e.g., Simon, 1969), where the search for a potential solution arises in a unitary problem space that is defined by a set of relatively stable design requirements and constraints.

Corresponding author:
Bo T. Christensen
bc.marktg@cbs.dk

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The co-evolution view of design was originally advanced by Mary Lou Maher (e.g., Maher, 1994, 2000; Maher & Poon, 1995, 1996; Poon & Maher, 1997), who drew on the biological concept of two species interacting so intimately that their evolutionary fitness depends on each other. By evoking this metaphor from nature, Maher advanced an artificial intelligence (AI) understanding of the way in which design problems and design solutions can both be modelled as evolving separately while having a mutual effect on one another. Subsequent to Maher's pioneering computational research on problem–solution co-evolution the concept has since gained particular momentum following Dorst and Cross's (2001) *Design Studies* article, which applied Maher's computational concept to a behavioural analysis of human creativity in the design process. Dorst and Cross proposed that their empirical data deriving from verbal protocol studies of experienced industrial designers corroborated the general validity of the co-evolution model. The Dorst and Cross (2001) article is now the second most cited paper in the present journal's history, with 218 citations recorded in Scopus (accessed 12 January 2013), attesting to the appeal and impact of the co-evolution concept.

Despite such widespread recognition of the apparent importance of problem–solution co-evolution in design, it is perhaps surprising that few follow-up studies can be found in the literature that systematically test the generality and applicability of the construct across different design domains, problem types, expertise levels and data collection methodologies. In the present paper we aim to advance research on problem–solution co-evolution by examining the capacity of the concept to capture aspects of creativity in professional, team-based design practice. It is the examination of co-evolution in *collaborative* design that we would argue represents one of the key elements of originality in our reported research. Before considering the specific aims and methodology of our study, however, we first examine the concept of problem–solution co-evolution in more detail so as to clarify the context and rationale for our own empirical contribution.

1 Problem–solution co-evolution in design: the computational perspective

Maher (1994; see also Maher & Poon, 1996) was the first researcher to propose a co-evolution model of design as involving an interaction between the problem space (i.e., the required behaviour of the design) and the solution space (i.e., the potential structural combinations that constitute the design). Both state spaces are viewed as interacting over a time spectrum (see Figure 1) and are assumed to be evolutionary systems, with the evolution of each space being guided by the most recent population of entities (i.e., alternative problem requirements or alternative solution possibilities) in the other space. As can be seen in Figure 1, evolution involves a horizontal process within a particular state space. On the other hand, diagonal movements reflect a search process, which can arise: (1) when the problem leads to a solution, as is the case,