Cognitive strategies of analogical reasoning in design: Differences between expert and novice designers

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This study investigates differences in analogical reasoning among first, second, and fourth year students and expert architects. Participants took part in an experiment consisting of four tasks: rating source examples, selecting a source domain, explaining their selection, and designing a bus stop. The results indicate significant differences among participants with respect to their soundness ratings. The results also show significant relation between level of expertise and participants' selection of source categories, the stated reasons for their selection, and the type of similarity they established between source and target. We conclude that experts preferred 'mental hops' while first year students preferred 'mental leaps.' Second and fourth year students preferred neither 'mental leaps' nor 'mental hops' but to literally copy the sources.

Keywords: analogical reasoning, architectural design, creativity, design cognition, design education

Analogical reasoning is described as a fundamental cognitive process underlying most other cognitive processes (Hofstadter, 2001), such as problem solving (Gick & Holyoak, 1980, 1983; Novick, 1988; Ross & Kilbane, 1997), scientific discovery (Dunbar & Blanchette, 2001; Gentner et al., 1997; Nersessian, 2008), learning (Brown, 1989; Vosniadou, 1989), and creativity (Johnson-Laird, 1989; Ward, 1998).

Gentner and Toupin (1986) claim that analogy is essential to both learning and discovery. Similarly, analogical reasoning plays a double role in design learning, supporting creativity and learning simultaneously. It is common among both architectural design students and practicing architects to browse through architectural publications in search of design examples that could be relevant to a design situation or for keeping up to date with recent projects. Furthermore, analogical thinking is a seminal learning strategy (Brown, 1989; Vosniadou, 1989) and enhances design learning. Design instructors often advise their students to enrich their visual vocabulary through studying masters' projects.

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www.elsevier.com/locate/destud
0142-694X $ - see front matter *Design Studies* **34** (2013) 161–192
http://dx.doi.org/10.1016/j.destud.2012.11.006

This study explores the role of analogy in design problem solving. It reports the results of an experimental study which investigated whether students from different levels of architectural education and expert architects differ from each other in the way they use analogy for a given design task. We specifically investigated the role of expertise in analogy, the impact of designers' goals on analogizing, and types of similarity established between sources and target domains. Compared to other similar research, this investigation included a larger and more diversified group of participants and used visual displays from four categories selected from a range of *near*, *near distant*, *medium distant*, and *distant* source examples. Furthermore, we identified the reasons for which subjects selected the specific source examples and source categories. The study makes a contribution to analogical reasoning in design by investigating the interaction among three factors: level of expertise, distance between source and target, and type of similarity established between source and target.

1 *Analogical reasoning and design*

The use of analogy in design is common. Kalogerakis, Lüthje, and Herstatt (2010) found that analogies are widely used by professionals working at design and engineering companies. Ball, Ormerod, and Morley (2004) demonstrated that spontaneous use of analogy is common among both novice and expert designers.

Studies of analogy in design provide a wide range of results, yet are inconclusive in establishing a consistent pattern with regard to experts' and novices' preferences for near and distant domain analogies. Some researchers have discussed the differences between novices and experts primarily in terms of differences in their knowledge structure (Casakin, 2004, 2010; Casakin & Goldschmidt, 1999). Others have specified the differences more in terms of differences in goals (Ball & Christensen, 2009; Kalogerakis et al., 2010), in instructions to use analogy (Dahl & Moreau, 2002), or in the representational format of the source analogues provided to the subjects (Cardoso & Badke-Schaub, 2011; Zahner, Nickerson, Tversky, Corter, & Ma, 2010).

Kalogerakis et al. (2010) found that experts often prefer medium range analogies rather than near or distant domain analogies. Their results indicate that the preference between near and distant analogies depends on the goal of the designer. Similarly, Ball and Christensen (2009) claim that the distance between the selected source and the target relates to the purpose of the designer. In their study they found that expert designers use more between-domain analogies. In contrast, Christensen and Schunn (2007) found that experts use both within-domain and between-domain analogies, but primarily within-domain, when trying out improvements to existing products. Bonnardel and Marmèche (2004) found that experts evoke more between-domain sources and more sources in total; and when provided with between-domain source examples they are more likely to expand their search.