Initial mental representations of design problems: Differences between experts and novices

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Defining and structuring wicked design problems has a major influence on subsequent problem solving, and demands a considerable level of skill. Previous research on mental representations in design is scarce, and has been largely based on students or individual experts. This study explored the differences in the initial mental representations of real-life product development problems between advanced product development engineering students and recommended, professional experts. Expert mental representations were found to demonstrate superior extent, depth and level of detail, accommodating more interconnections and being more geared toward action. The results indicate that targeting relevancy perceptions to locate interconnections and promote proactivity can be a key factor in developing product development education to better match the requirements faced by professionals.

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Expertise, i.e. superior performance in representative tasks in the field of expertise (Ericsson & Lehmann, 1996; Ericsson & Smith, 1991), has been studied in diverse domains and numerous professions, and systematic differences have long been demonstrated between expert and novice problem solving performance (Chi, Glaser & Farr, 1988; Ericsson, Charness, Feltovich, & Hoffman, 2006). However, limited research has been conducted on product development expertise (Cross, 2003; Defazio, 2008; Lawson, 2004), and in general, expertise and decision making research has tended to focus on fields with relatively well-defined problems, such as games and sports. While well-defined tasks are associated with a clear initial state, goal state, and set of rules (Reitman, 1965; Simon, 1973), many of the problem parameters are vague or unknown in the ill-structured creative problems faced in creative knowledge work. Indeed, previous design research has identified that it is not only the domain that distinguishes design from other fields, but also the process in which it is carried out (Gero, 1990). The design process seems to fundamentally differ from the scientific method (Lawson, 1979). Whereas a strategy of analysis and synthesis works for well-defined problems

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(Reitman, 1965; Simon, 1973), the exploration process of ill-structured problems is targeted at both goal and decision variables (Gero, 1990). The problem must first be transformed or structured into a clear mental representation of the current situation and goal state by the problem solver (Simon, 1973). In addition, fruitful actions need to be recognized from irrelevant ones from a seemingly unlimited pool of possible options (Schunn, McGregor, & Saner, 2005). As creative knowledge-work professionals such as product developers need to routinely deal with these 'messy situations' (Schön, 1983), how the problems are perceived and represented are of particular interest (Lawson, 2004).

Coined as wicked problems in design literature (Buchanan, 1992; Rittel & Webber, 1973), there is no 'right' way to represent such vague problems. Rather the problem representation develops hand in hand with the solution, and the 'information needed to *understand* the problem depends upon one's idea for *solving* it' (Rittel & Webber, 1973, 161, italics original). How the problem is perceived influences which solutions are considered as relevant (Getzels, 1975), and thus finding the solution requires the problem to be formulated in a fruitful way (Getzels, 1979). Indeed, the creation or adaptation of a fruitful *frame* has been identified as a key practice in design and design thinking (Beckman & Barry, 2007; Dorst, 2011; Drews, 2009; Paton & Dorst, 2010), as well as in creative work in general (Hargadon & Bechky, 2006; Schank & Abelson, 1977). Framing refers to the creation of a standpoint from which a problem can be successfully tackled (Dorst, 2011), and requires a process of structuring and formulating the problem (Cross, 2004b). Whereas design problems can have some inherent structure, for example in terms of the number of main issues or amount of dependencies between issues (Dorst, 1996), problem structuring refers to the psychological process of forming a mental, subjective representation reflecting the perceived problem state and desired outcome (Simon, 1973). The significance of the mental representation that is formed by the designer is further highlighted by the nature of design briefs in development work – at the starting point of a project, the client's initial expression of the design problem is reframed by the product developer and the client in a process of briefing in order to create a fruitful and actionable view of the project (Hey, Joyce, & Beckman, 2007; Paton & Dorst, 2010; Schön & Wiggins, 1992; Valkenburg & Dorst, 1998). In other words, designers must interpret the input they receive or collect regarding a design project in order to create a first representation of the problem at hand (Visser, 2006). As the requirements co-evolve with the solution (Dorst & Cross, 2001; Kolodner & Wills, 1996; Suwa, Gero, & Purcell, 2000) and affect its quality (Chakrabarti, Morgenstern, & Knaab, 2004; Walz, Elan, & Curtis, 1993), the first representation created by the product developer has a significant impact on the entire subsequent development project, and posits itself as both a meaningful and an intriguing research arena. However, despite the rise of expert mental representation research in other fields (Bläsing, Tenenbaum, &