# *Activity Theory as a means for multi-scale analysis of the engineering design process: A protocol study of design in practice*

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*This paper contributes to improving our understanding of design activity. Specifically the paper uses Activity Theory to enable a multi-scale analysis of the activity of three engineering designers over a period of one month. Correspondingly, this paper represents the first work that explicitly investigates design activity across different scales, referred to as macro-, meso- and micro-scales. In addition to establishing the range of activities and tasks that occur at, and constitute, each scale the underlying relationships between the scales of activity are discussed. Further, the paper elucidates the wider implications of the proposed framework and its findings for both design research and practice. Central to these implications is the articulation of design as a complex fabric of interwoven processes.*


*Keywords: case study, design activity, design practice, protocol analysis*

Understanding, and describing the design process has been a focus of design research since its inception (Cross, 2007; Pahl & Beitz, 1996). Being able to describe the activities and cycles associated with a successful design process, and subsequent design outcome, form some of the fundamental ambitions of the field (Finger & Dixon, 1989a, 1989b; Horvath, 2004). The scope of this ambition is illustrated by two perspectives widely represented in current design research literature. First, fine grain approaches are used to understand the details of micro-scale cycles or processes linked to design performance e.g. design cognition for shared mental models (Dong, Kleinsmann, & Deken, 2013). Second, coarse grain approaches are used to map wider, macro-scale, processes or overall features of design activity e.g. stage based descriptions of design (Cooper, Edgett, & Kleinschmidt, 2002; French, 1998). Here each type of approach is facilitated by, and results in, explanative frameworks or models appropriate to that type of research e.g. micro-scale team interaction models (Dorst & Cross, 2001; Gero & Kannengiesser, 2004; Visser, 2010), or macro-scale associations between total

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time spent on a specific activity and overall performance (Robinson, 2010; Wasiak, Hicks, Newnes, Dong, & Burrow, 2010). Despite the strengths of these individual perspectives, they by necessity adopt empirical methods applicable to the different scales (Lethbridge, Sim, & Singer, 2005). Consequentially, this leads to a fundamental issue when considering, and trying to bring together, these different aspects of the design research domain (McMahon, 2012): The difficulty in exploring and characterising if, and how, micro-scale and macro-scale features are related, and what exists in the middle ground.

Although comparisons exist within a scale, the Authors have been unable to identify extant studies that span the scales. For example, consider the recent work of Cash, Hicks, and Culley (2013), where situations were compared in practice and in the lab. Although this focused on bringing together research perspectives, it was limited to micro-scale features and was fundamentally informed by the designer level perspective. Also consider the debates surrounding differences between practitioners and students (Ahmed, Wallace, & Blessing, 2003; Kavakli & Gero, 2002; Seitamaa-Hakkarainen & Hakkarainen, 2001). Here there are many comparisons at each scale but few studies bridging experimental and longitudinal data in order to more fully understand the implications of short-term differentiation. The lack of consideration of multi-scale relationships is further illustrated by Robinson's (2010) work on information behaviours. Although this is notable for its method's longitudinal quality, it is also limited by the difficulty in linking to the micro-scale structures of minute-by-minute information seeking. This fundamentally limits the understanding that can be generated from comparisons between studies. Hence it can be argued that, as with any technical system, the ability to describe behaviours and properties of the system across multiple scales is essential for generating deep scientific understanding. This is further supported by the importance of Activity Theory in the study of human behaviour (Bedny & Harris, 2005), and the concept of multi-level theory building in the management domain (Klein, Tosi, & Cannella, 1999). Further, this is true also for social-technical systems, such as, the activity of design, and thus the exploration and consideration of multiple scales is an important element in furthering the understanding of design as a whole.

Ultimately these points can be distilled into the driving questions for this paper: *At what scales do distinct design activities and tasks exist and how are the various scales related?*

In order to explore this question, the work develops a multi-scale analysis approach based on Activity Theory. This is applied to a protocol study of design in practice. Specifically, a fine grain protocol analysis is used to describe a longer period of design activity in order to facilitate analysis at different