4 Distributed Cognition in Engineering Design: Negotiating between Abstract and Material Representations

Margot Brereton

Introduction

Recent writings on cognition have focused on the contribution of external representations in supporting internal thought processes. External representations have been found to be so instrumental to thought that cognition is described as "distributed." "Distributed cognition" refers to the way that cognitive achievements arise from not only the internal thought processes of people, but also from the external representations such as the material systems, sketches and information technologies with which they work. The term "distributed" also refers to the fact that thinking processes may be distributed among members of a social group. This chapter focuses on how material representations – prototypes and bits of hardware – are instrumental to thinking in engineering design. In the closing discussion, extensions to other fields of design are considered.

In influential early writings on distributed cognition, Hutchins (1995) described the activities of navigation as the cooperative achievements of humans with technologies. Goodwin (1990) discussed interactive processes that involved technologies and physical apparatus on an oceanographic research vessel. Chaiklin and Lave (1993) analyzed how a blacksmith worked with materials as he designed and made a piece. In related design research, Schön (1994) described the process of designing as a reflective conversation with the materials of a design situation. Harrison and Minneman (1996) described how objects are an integral part of design communications, altering the dynamics in multi-designer settings and forming part of the pool of representations that are drawn on by designers.

While this chapter uses the term "distributed cognition" to describe the process of designing and developing design understandings, this should not be taken to imply a commitment to the cognitivist tradition of studying thinking. No attempt is made to understand or depict the internal workings of the designer's mind, to which we have no direct access. Further, this chapter does not speculate on the issues of perception or internal representation.

The epistemological stance taken here recognizes that the designer's internal thought processes contribute to the development of design understandings, but regards knowledge as fundamentally social in origin – that is, knowledge and information lie within the social milieu of people, artefacts, books, the world etc., and people access and construct this information into personal knowledge through their interaction with the social milieu and the lived world. This stance is drawn from the tradition of phenomenology after Husserl (Macann 1993), the extension of phenomenology to the social world after Schutz (1932; see also Dourish 2001) and the social constructivist learning philosophy attributed to Vygotsky (Moll 1990). Hence the study of design described in this chapter used methods that were derived from the social sciences.

This chapter demonstrates how material systems are used in engineering activity to support: a) thinking in design and b) learning fundamental engineering concepts. Specifically, I will demonstrate that learning in design is enabled through continually challenging abstract representations against material representations. This comparison between representations reveals gaps that inspire further design activity. The cycle of representation and re-representation in abstract and material forms advances the design, advances the designer's understanding of design requirements, reveals hitherto implicit design assumptions, and extends the designer's hardware repertoire of familiar hardware components and machines. In addition to informing design activity, this process of re-representation assists students in sorting out fundamental engineering concepts. The chapter draws on videotape data of design activity in order to illustrate the use of material and abstract representations by designers. First I define the different types of representations that are referred to below.

Types of Design Representations

There are four dimensions with which it is useful to classify representations when considering their use by designers. These dimensions are shown in Figure 4.1.

Internal vs. external

Representations can be classified as internal or external. Internal representations are those thoughts in the designer's mind to which a researcher does not have direct access. External representations of design thinking are spoken utterances, written lists, drawings, prototypes, etc. These external representations are directly available to the design researcher and to other designers during the normal social interactions of a design team.