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Integrating ergonomics into engineering design: The role of objects

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ABSTRACT

The objective of this study was to explore the role of objects in integrating ergonomic knowledge in engineering design processes. An engineering design case was analyzed using the theoretical concepts of *boundary objects* and *intermediary objects*: Boundary objects facilitate collaboration between different knowledge domains, while the aim of an intermediary object is to circulate knowledge and thus produce a distant effect. Adjustable layout drawings served as boundary objects and had a positive impact on the dialog between an ergonomist and designers. An ergonomic guideline document was identified as an intermediary object. However, when the ergonomic guidelines were circulated in the design process, only some of the guidelines were transferred to the design of the sterile processing plant. Based on these findings, recommendations for working with objects in design processes are included.

1. Introduction

Integrating ergonomics into engineering design of new workplaces and production systems is believed to be an important proactive strategy to enhance good working conditions and production efficiency (Broberg, 2010; Dul and Neumann, 2009; Jensen, 2002; Hendrick, 2008, Neumann et al., 2006, 2009). A widespread approach to integrate ergonomic knowledge in engineering design is to provide the designers with information on ergonomics, through for instance ergonomic standards or handbooks. Studies have however indicated that this approach alone does not ensure successful integration (Broberg, 2007; Burns and Vicente, 1994; Campbell, 1996; Helander, 1999; Rogers and Armstrong, 1977). Wulff et al. (1999a,b) have studied the integration of ergonomics in large-scale engineering design in the offshore industry in Norway. Here, documents containing ergonomic requirements were distributed within the design organization under the assumption that designers would integrate the requirements in their workspace design. Wulff et al. (1999a,b) found, however, that the requirements were not well known in the design organization, and even when the designers did know the requirements, they were not all integrated into the final design. Some requirements were difficult for the designers to interpret, while others created a situation of conflicting criteria. These findings illustrate possible limitations to using objects like documents to pass on ergonomic knowledge in design processes. However, so far, the human factors (HF) has not given much attention to a broader focus on how different objects can help or limit integration of ergonomic knowledge in design processes.

1.1. Theoretical perspectives on objects

Traditionally, engineering designers have viewed objects, such as drawings and prototypes, as neutral: Objects are means of coming from an idea to a result (Vinck et al., 1996). A different view of objects is found within the Science and Technology Studies (STS) tradition. STS has focused on the role of different objects for several years. Objects here are regarded as mediators that can play an active role in design processes (Vinck et al., 1996), and as a result, different theoretical concepts have been developed. The concepts of *boundary objects* and *intermediary objects*, which are presented below, have been used successfully to create new insights and a greater understanding of the role of objects in design processes (Boujut and Blanco, 2003; Carlile, 2002).

I) The concept of *boundary objects* was introduced in Star and Griesemer's (1989) studies of scientific work. Star and Griesemer (1989) focused on the heterogeneous nature of scientific work and introduced the concept of boundary objects as a way to manage the tension at the boundary between diverse groups of actors. According to Star and Griesemer (1989), different groups of actors belong to different social worlds, and when they work together,

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boundary objects can help establish a shared context between them that helps create common understanding of the subject in question. The nature of the boundary objects "*is reflected by the fact that they are simultaneously concrete and abstract, specific and general, conventionalized and customized*" (Star and Griesemer, 1989). Carlile (2002) drew on the work of Star and Griesemer and introduced the concept of boundary objects to the area of new product development. He found that objects such as assembly drawings can be useful when cooperating across different knowledge domains in a design process. He identified three characteristics of a useful boundary object: It "*establishes a shared syntax or language for individuals to represent their knowledge*"; secondly, it "*provides a concrete means for individuals to specify and learn about their differences and dependencies across a given boundary*"; and finally, it "*facilitates a process where individuals can jointly transform their knowledge*" (Carlile, 2002, pp. 451–452). In this paper, we define *boundary objects* as objects that function as mediators in the direct communication between actors.

II) In contrast to the concept of boundary objects, we introduce the concept of *intermediary objects*. These objects are used as a means of transferring and sustaining knowledge, for instance, in a design process, when actors may not be able to meet in person. The concept was developed by Callon (1992), who presented four different types of intermediaries: texts, technical artifacts, human beings and their skills, and money. In this paper, we focus on texts. An intermediary object is an object produced by a network of designers with the specific intent of transferring their knowledge and experience to downstream actors. In relation to workplace design, the aim of the designers is to affect the final design of the workplace from a distance. An intermediary object, however, creates a new point of departure, and downstream actors might not comply with the intentions embedded in the object: After receiving an intermediary object, downstream actors do not necessarily just transfer the content of the object. When relating the object to their own profession or work practice, downstream actors may ignore or alter different parts of the intermediary object and thus transform the content of the intermediary object according to their own interest, purpose or profession (Gherardi and Nicolini, 2000; Vinck et al., 1996).

Vinck et al. (1996) address the view and characteristics of intermediary objects by distinguishing between "open" and "closed" objects. The characteristics of a "closed" object refer to the designers' intention: The users are not supposed to interpret or transform the intentions embedded in the object, rather to comply with them. The characteristics of an "open" object are, on the other hand, related to the *interpretive flexibility* of a given object, which is bound to the use of the object. When an object is interpreted and modified by the various users of the object, it is considered to be "open" (Broberg et al., 2011; Vinck et al., 1996). In an ergonomic context an example of an intermediary object is an ergonomic standard, which from the outset is produced as a "closed" object intended to *transfer* knowledge from ergonomists to other design actors. Whether or not the standard succeeds will depend, however, on the users interpretation of the standard as either a "closed" or an "open" object.

1.2. Objects in HF literature

A few studies in the HF literature draw on the STS tradition and indicate that different kinds of objects can play an important role in integrating ergonomics. In the area of participatory ergonomics, Broberg et al. (2011) find that the characteristics of boundary objects are of great importance in enabling user participation and collaboration in design. One of the important characteristics is *flexible and malleable* objects, as this characteristic creates the possibility to do rapid prototyping of design solutions. In another study, Conceição et al. (2012) develop two intermediary objects, a recommendation booklet and a zoning pattern, in order to transfer ergonomic knowledge and user experience to designers working in the offshore industry. In this industry, face-to-face meetings between users and designers are not always possible, which makes information transfer via objects unavoidable. At workshops with engineering designers, the usability of the two intermediary objects was evaluated as positive, and they were recommended for use in future design processes. Both studies were based on objects designed by researchers. Objects developed in a 'natural' design process, without the participation of researchers, have not been given much attention in the HF literature so far.

1.3. Aim of the study and use of the concepts

The aim of this study is to provide greater understanding of the role of objects used in 'natural' design processes where ergonomic knowledge is integrated into engineering design processes. We seek to gain this understanding by applying the concepts of *boundary objects* and *intermediary objects* in an analysis of an engineering design case in which an ergonomist participated in the design process. Both theoretical concepts provide the possibility to enhance our understanding of the different roles an object might play during the integration of ergonomic knowledge into engineering design processes.

The paper is concluded by providing implications for both ergonomists and engineering designers.

2. Method

An explorative case study (Thomas, 2011) was carried out in an engineering consultancy firm for the purpose of increasing understanding of the role objects play in the process of integrating ergonomic knowledge in design. We begin by describing the case scenario.

2.1. The setting

An engineering consultancy firm was hired by a hospital to design a sterile processing plant. The design task involved designing the logistics and layout to deliver as a project proposal for the hospital and their building contractor. The design team included engineers with different areas of expertise; a consultant (C1) who was a trained nurse; a project manager (PM) who was an engineer and the head of the hospital division.

The physical space designated for the sterile processing plant was rather cramped; therefore, the project team decided to involve one of the engineering consultancy firm's own ergonomists in the project. The coordinator of the ergonomists' "hospital group" was in charge of selecting the ergonomist to assign to the design job. Based on his experience from other design jobs, he selected a trained physiotherapist. The ergonomist's job was to make sure that the design proposal complied with existing occupational health and safety (OHS) legislation, and to complete an ergonomic guideline document (EGD) with her recommendations for the design.

After the design proposal had been completed and submitted, the hospital contacted the engineering consultancy firm again for assistance during both the construction and start-up phases at the