Safety Science 81 (2016) 90–98

Contents lists available at ScienceDirect

Safety Science

journal homepage: www.elsevier.com/locate/ssci

Cultural features of design and shared learning for safety: A Nordic nuclear industry perspective

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ARTICLE INFO

Article history:
Received 31 October 2014
Received in revised form 30 March 2015
Accepted 11 April 2015
Available online 2 May 2015

Keywords:
Safety culture
Design
Shared learning
Cultural features
Nuclear industry

ABSTRACT

Safe and functional nuclear industry design is a topic of growing interest due to new builds and modernization projects in the operating nuclear power plants. Provided that good design of components and systems is critical for safe operation of the plants, understanding what influences the process of learning for safety in design activities is of utmost importance. The existing literature emphasizes tensions of design activity but pays insufficient attention to the culture of design and its relation to safety and learning. This paper aims at identifying cultural features of design organizations, such as shared conceptions, assumptions, norms, beliefs, and exploring their influence on the process of shared learning for safety. Case studies were carried out in Finland and Sweden to generate insights on cultural characteristics of design in the nuclear domain. The paper indicates the importance of requirements as a media for sharing knowledge and learning in nuclear industry design projects. As the networked aspects of the design work are gradually acknowledged, the need to learn how to systematically manage the requirements and understand the big picture of the overall design project are highlighted.

1. Introduction

Following the Fukushima accident in 2011, considerations have been given to the role of nuclear power plant design in the context of extreme external events. In recent years, the International Atomic Energy Agency (IAEA, 2012) emphasized the importance of a good safety culture in design and construction phases of new builds. Various design modernizations are required also for the safe lifetime extension of the aging operational nuclear power plants. The Nordic nuclear industry represents especially suitable study context in this respect, as a new nuclear build with a first-of-a-kind reactor design is currently under construction in Finland (Olkiluoto 3), and various modernization projects are taking place in the operating nuclear power plants in Northern Europe.

Design phase plays a critical role for enhancing system safety in the nuclear industry because it sets requirements for the whole nuclear plant lifecycle, ranging from manufacturing and construction to maintenance and decommissioning. As Hale et al. (2007) put it, "systems development begin with design and so design offers the earliest, and hopefully the cheapest place to intervene and get it right." As organizations gradually learn ways to deal with pressures in the course of external adaptation and internal integration, they develop their specific *culture*, which further frame their activities and performance (Schein, 1992). The essence of "engineering" (or "design") culture differs from the executive and operators organizational cultures insofar as it values technical and error-free solutions: "technical elegance and simplicity of solutions is a primary value, and solutions must be efficient and error free [...] the best solutions should be free of humans altogether" (Schein, 1996). At the same time, one of the main assumptions of the design culture is that engineers are "safety oriented and overdesign for safety". Although Schein indicated that the

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http://dx.doi.org/10.1016/j.ssci.2015.04.014
0925-7535/

alignment of these three cultures – executives, operators and designers – can facilitate organizational learning, it remains unclear what specific cultural features influence designers toward striving for enhanced safety of the components, structures and systems. Designers are influenced by cultural issues as much as the other actors involved in a nuclear power project; an issue, which has not been extensively discussed in the nuclear industry research (Macchi et al., 2013).

In general, *learning* can be understood as improvement of practices and routines (Cook and Brown, 1999) and as a marked "increase in the repertoire of behaviours" (Grote and Carroll, 2014), based on acquiring of new knowledge, skills or understanding. Several studies found that the willingness to transfer knowledge in organizations is enhanced by face-to-face communications and physical proximity (Håkansson, 1992; Nonaka and Takeuchi, 1995; Ahuja and Carley, 1999; Wiesenfeld et al., 1999). However, in complex nuclear projects such means for learning are challenged due to the distributed nature of activities, dynamic changes, and different cultural, legal, and language contexts. In a multi-firm project partners exchange and co-create knowledge and capabilities but they also compete and try to protect their own benefits.

Based on their study of the Challenger and Columbia accidents, Mahler and Casamayou (2009: 196) argued that learning is especially important in safety-critical industries because the "missed opportunities for learning, learning the wrong lessons, or forgetting the important ones" can have large-scale and long-term consequences. Although organizational learning takes a central role in safety-critical domains, the main focus is rather retrospective, that is, learning from past incidents, accidents and near misses (Doytchev and Hibberd, 2009; Wahlström, 2011). Recently, Drupsteen and Guldenmund (2014) carried out a literature review on organizational learning and safety, and emphasized that although learning is recognized as a key process for improving safety in organizations, lessons learned are insufficiently shared and conditions for learning have received limited research attention. IAEA (1991) stated that in the nuclear industry "learning is enabled through the ability to recognize and diagnose deviations, formulate and implement solutions and monitor the effects of corrective actions". However, it is challenging to develop this ability in design organizations since the designed artefacts are not yet functioning and it is difficult to detect deviations beforehand as they might potentially actualize during their testing period or the long operation time.

The aim of this paper is to provide new insights on *how the culture of design affects shared learning for safety* in the nuclear industry. In this study, *shared learning* for safety is seen as a dynamic process of constructing knowledge and understanding through interactions between actors involved in design activities. What means are used to discuss and communicate relevant information and knowledge in design projects? How does shared learning for safety take place in an "organization", which is a dynamic network of actors, representing different companies and countries? The design process in the Nordic nuclear industry is analyzed from safety culture perspective. The ability and willingness to handle risks associated with the nuclear power production form the core of a good *safety culture* (Reiman et al., 2012). However, in the case of new builds design, the relevance of the safety culture concept is challenged by the fact that the nuclear fuel and the associated hazards are not yet present at the site. In this context it is important to understand how designers learn to take care for safety of their end-products as elements of complex systems. A broad view on design activities is taken in the article, ranging from the ideation to the practical implementation and installation of the design solution, its further development, and overall project design.

2. Theoretical perspectives on design

Design consists of ideas conception, planning and explaining, making decisions related to the development of the ideas, management of activities and solving a problem (Lawrence, 1988; Aspelund, 2006). Previous literature indicated the inherent tensions and practical challenges in the design work (e.g., Gero, 1990, 1996; Mark et al., 2007). Design is seen as a goal-oriented and problem-solving activity, which represents both *process* and *outcome* (Borja de Motoza, 2003). Further, it is viewed both as an *individual performance* and *collective coordination* (Curtis et al., 1988). Design includes *analytical and creative features*, since design problems as seen as novel and related to uncertainty, yet related to fulfilling concrete requirements for achieving a practical goal (Cross, 1982; Trueman, 1998). Regarding these tensions, Schön (1983) compares design to "tightrope walking" as a balancing and an action-oriented activity, which is often tacit and difficult to express. He characterized design as 'reflective practice', referring to the need to apply its artistic and intuitive features into real-life situations of "uncertainty, instability, uniqueness, and value conflict."

The future-orientation of design is highlighted by Goel and Pirolli (1992), as they refer to design activity as involving mental formulation of future states of affairs. Still, *the present and future conditions* are considered *simultaneously* by researchers, exploring design by using complexity lens. Veland (2010) argued that "real-world design problems typically involve several dimensions of complexity: technical complexity, social complexity and problem "wickedness" (e.g. problems that are ill-defined and tricky), thus design should tackle these challenges holistically and in an "iterative way as insights are gained throughout the project". The design process is described as emergent, alternating between problem definition and solution, and characterized by imagination, prototyping, and understanding the user requirements (Conklin, 2006; Lawson, 2006). Normative perspective on design process views it as composed of certain phases, such as analysis of requirements, synthesis to find possible creative solutions with the least compromise, and evaluation as checking the accuracy with the requirements and implementing the solution (Jones, 1984). However, design is not a linear process from problems to solutions; it requires rounds of iteration between the problem and solution area. Integrative models of design process emphasize the simultaneous exploration of problems and solutions by designers (Cross, 1999; Andriopoulos and Lewis, 2010).

Design requires "design thinking", which is a solution-focused approach for exploring the parameters of the problem and possible practical solutions at the same time (Cross, 1982; Veland, 2010). Design thinking is seen as "a balance between the right-brain and left-brain thinking" (Martin, 2009); a combination of "empathy for the context of a problem, creativity in the generation of insights and solutions, and rationality in analysing and fitting various solutions to the problem context" (Kelley and Kelley, 2013). The blending of ideation and practicality is captured by the concept of *sketching*: as some designers put it, "I think with my hands" (Collopy, 2004), or "design gets down and dirty" (Buxton, 2010). Sketching is seen as an informal media, which helps designers to communicate their ideas to other stakeholders so that the final design artefact fulfils multidisciplinary requirements (Cross, 1984; Yang, 2009). Some authors emphasize that design allows heterogeneous knowledge to be integrated and transformed under uncertainly (Norros, 2004; Mark et al., 2007). Grabher (2004) analyzed processes of project-based learning and found that they are largely driven by the *opposing logics* of *creating* and *harmonizing knowledge*. Also Easterby-Smith et al. (2000) indicated the need to address learning in the light of the *inherent conflicts* between