Organizational knowledge in high-risk industries: What are the alternatives to model-based learning approaches?

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Abstract

The underlying idea of this paper is the contrasting of a 'model-based' and a 'human inquiry based' view of knowledge and learning. A model-based approach to learning means to focus on information processing, dissemination, and transfer of information, knowledge and experience. Learning and knowledge transfer will then be achieved as long as information is processed and distributed (e.g. Huber, 1991). A human inquiry based approach is in many ways opposite to the model-based approach. Learning is regarded as a process of subjective, interpretive, meaning making (Boland & Tenkasi, 1995). We draw attention to the limitations of the information processing models and the potentials of a human inquiry based approach where learning is viewed as a social construction, putting knowledge and experience back into the contexts in which they have meaning (Brown & Duguid, 1991; Wenger, 1998; Cook & Brown, 1999).

High-risk industries are often facing a dilemma in their approach to creating a more competent and safe industry: They are excluded from some of the most effective learning processes such as trial-and-error learning and learning from failures and mistakes, and forced to rely on formal models of information gathering and dissemination often shown to be ineffective and unreliable. In the paper we shall discuss if this is a dilemma without answer, or if there are other elements or approaches of human inquiry that are feasible also in a high-risk context?

In high-risk industries failures, mistakes and errors will often not be tolerated due to the potentially catastrophic outcome associated with mistakes. To overcome these problems, such organizations must develop alternatives to experimentation and trial-and-error learning. They must learn as much as possible from minor precursor problems, transfer learning effectively across organizations, and improve their processes based on proactive learning (Carroll, 1998a; Weick et al, 1999).

The paper draws on empirical data and studies conducted in the Norwegian oil and gas industry (Aase, 1997). These studies show that learning and knowledge transfer is typically organized around the model-based view of knowledge and learning as the dissemination of fact-type information (easily coded and made explicit). Considerably resources are devoted to the development and implications of databases, specifications, and other formal instruments to codify and conserve knowledge and experience. Such formal repositories of experience and knowledge often fail to achieve their expected impact. People working in offshore development projects often find that face-to-face interaction and informal channels of experience and knowledge (e.g. personal networks) better serve their information and knowledge needs. Our assertion is that the requirements of transferring experience and developing knowledge in more uncertain and organizationally driven domains imply a human inquiry approach to collectively develop, make sense of, and disseminate tacit and sticky knowledge.

The main objective of the paper is to describe the background for, and to explore and identify different learning approaches that meet the conditions of the human inquiry perspective to organizational knowledge in high-risk industries. The human inquiry perspective implies that aspects of experimentation, commitment, interaction, collective thinking, and mental models should form the basis of these learning approaches. The trying conditions of high-risk industries regarding the potential for catastrophic consequences and interactively complex technology require even more savoir-faire in the development of such human inquiry based learning approaches. In this setting, elements of imagination, intelligent failure promotion, stories, collective training, and case studies will be introduced with the aim of improving the learning conditions in high-risk industries.

1. Introduction

"I felt that the organizational knowledge project had more potential than we managed to take out of it. This was mainly because we focused so much on the procedures and because we didn't have enough time. In addition, our manager wanted something safe and concrete" (project safety engineer).

"The operating departments and installations have not seen it as their responsibility to transfer knowledge and experience to new projects. And if they have tried, the projects have not been willing to receive it. There are two phases in a project; either it's too early, or it's too late!" (safety manager).

"I'm afraid organizational knowledge initiatives become very bureaucratic. Where I was earlier, they implemented a system with procedures and stuff to write down everything one did right or wrong each day. And you were supposed to comment on a number of things. And then you don't manage to separate the essential from the unessential" (staff support personnel)

"The work is like a train going in 100 miles/hour. Sometime it's good to stop a little. That was a positive effect of the learning case studies. People have seen it as a breathing space" (project engineer).

This paper is about organizational knowledge and learning under non-ideal conditions. No success criteria will be reported. No easy solutions are presented. A set of ideal learning conditions like shared visions, openness for change, room for experimentation, redundancy, or requisite variety is not present. The paper is rather a story of a countless number of insurmountable prerequisites for organizational knowledge and learning.

The main objective of the paper is to explore some of the learning conditions or learning constraints of high-risk industries. A dichotomy of a model-based perspective versus a human inquiry based perspective to organizational knowledge and learning will be used to create a backcloth for understanding the actions taken, and the approaches designed, in achieving learning in organizations. Together with learning characteristics and learning constraints of high-risk industries, the aim of the paper is to picture a possible action repertoire within learning of safe work practices. The paper draws on research conducted in the Norwegian oil

& gas industry in the period of 1992-2000 (Aase, 1997; Aase, 1998; Aase & Ringstad, 1999; Husemoen, 1997; Pedersen & Aase, 2001; Svidal, 2002; Sørensen, 1996; Wulff, 1997).

2. Contrasting perspectives on organizational knowledge

Knowledge comes in many forms. Knowledge is multi-faceted and complex, being situated and abstract, implicit and explicit, distributed and individual, physical and mental, developing and static, verbal and encoded. In the organizational learning literature, knowledge can be denoted as embrained, embodied, encultured, embedded or encoded (Blackler, 1995). Unlike information, knowledge is about action. Traditionally, knowledge has been viewed as something people possess, called the epistemology of possession. Knowledge in organizations has recently been subject to extensive research within the organization study literature. Yet, even in this growing body of literature that explores epistemologically significant themes, there typically remains an expressed or implied tendency to treat knowledge as being essentially of the 'possession' kind. The literature tends to privilege the individual over the group, and the explicit over the tacit (Cook & Brown, 1999: 382). Growing from the knowledge in action philosophy, Cook & Brown call for a knowledge epistemology of practice. They claim that organizations are better understood if explicit, tacit, individual and group knowledge are treated as four distinct and coequal forms of knowledge. Thus, the epistemology of possession and the epistemology of practice should be seen as mutually enabling and not competing. In the recent years, several authors have pinpointed a similar duality in organizational knowledge perspectives, using different dichotomies such as codification vs. personalization strategy (Hansen et al, 1999), information processing mode vs. narrative mode (Boland & Tenkasi, 1995), or epistemology of possession vs. epistemology of practice (Cook & Brown, 1999). In this paper, the distinction between a 'model-based' vs. a 'human inquiry based' perspective will be used, based on empirical findings in studies of a high-risk industry (Aase, 1997; Pedersen & Aase, 2001).

A model-based approach to organizational knowledge and learning means to focus on information processing, dissemination, and transfer of information, knowledge and experience. Learning and knowledge transfer will then be achieved as long as information is processed and distributed. Huber (1991) views organizational knowledge and learning using

an information processing model, stating that "*when information is widely distributed in an organization, so that more and more varied sources for it exist, retrieval efforts are more likely to succeed and individuals and units are more likely to be able to learn*" (p. 100). Learning within the model-based perspective means disseminating and utilizing knowledge that is explicit or codified, transmittable in formal, systematic language.

A human inquiry based approach is in many ways opposite to the model-based approach. Organizational knowledge and learning is regarded as a process of subjective, interpretive, meaning making (Boland et al., 1994). Information processing models for learning are rejected, and learning is viewed as social construction, putting knowledge and experience back into the contexts in which it has meaning (Brown & Duguid, 1991). Nonaka (1994) is a frequently cited advocate of the human inquiry perspective. He emphasizes aspects of reflection dialogue, socialization and externalization in his work on knowledge creation. The human inquiry approach is based on the premise stated by Nonaka as "*knowledge that can be expressed in words and numbers only represent the tip of the iceberg of the entire body of possible knowledge*" (p.16).

An organization is faced with a multitude of means suitable for organizational knowledge. Formal means are characterized by the integration of organizational knowledge in written routines and documents such as databases, policies, procedures, responsibility matrixes and job descriptions. Informal means focus on the integration of organizational knowledge into working practice. Common examples are seminars, courses, training programs, mentoring, case studies, professional networks and social events (Pedersen & Aase, 2001). Formal means are typically more structured and hence easier to control compared to informal means. The content can be described as one-way explicit information. Informal means, although more unstructured and spontaneous, represents a richer source of information incorporating both tacit and explicit knowledge. Informal means exceed formal tools in terms of richness and the ability to integrate and development new knowledge throughout the organization. Nevertheless, a large number of studies demonstrate the prevailing preference among business managers for formal means (Cook & Brown, 1999; McDermott, 1999; Ruggles, 1998; Swan et al, 1999).

Table 1 shows the characteristics of the model-based and human inquiry based perspective to organizational knowledge and learning. Examples of corresponding means for organizational

knowledge are provided from studies in the Norwegian oil and gas industry (Aase, 1997; Pedersen & Aase, 2001).

MODEL-BASED PERSPECTIVE	**HUMAN INQUIRY PERSPECTIVE**
Focus on information processing and dissemination	*Focus on participation and collaboration*
Syntactic information	Semantic information
'Simple' information	'Sticky' information
Lean information	Rich information
Explicit knowledge	Tacit knowledge
Closeness (individually-based)	Socialization (sharing of tacit knowledge)
Internalization (tacit remain tacit)	Externalization (from tacit to explicit)
FORMAL MEANS	**INFORMAL MEANS**
Focus on codified knowledge	*Focus on knowledge in practice*
Procedure and requirement handbooks	Informal contacts/ personal networks
Knowledge/ experience databases	Personnel rotation
Written experience reports	Seminars/ courses/ meetings/ forums
Formalized networks	Professional networks
Systematic experience-collecting efforts	Dialogue-based case studies
Job descriptions	Training programs

Table 1. Contrasting approaches to organizational knowledge

Researchers and practitioners have devoted considerable resources to the development and implications of databases, specifications and other formal instruments to codify and conserve knowledge and experience. Aase (1997) documents the weaknesses of model-based approaches in Norwegian oil and gas industry, whereas corresponding data and research on human inquiry approaches is still needed. Studies of offshore development projects show that formal repositories of experience and knowledge often fail to achieve their expected impact (Aase, 1997; Wulff, 1997). People working in development projects often find that face-to-face interaction and informal channels of experience and knowledge (e.g. personal networks) better serve their information needs.

2. High-risk industries

High-risk industries are characterized by the overall demand for high reliability because of their unique potentials for catastrophic consequences. Characteristics like complexity, interdependencies (Perrow, 1986), and proximity to hazard (Reason, 1997) can be used to categorize different types of high-risk industries. Organizations commonly denoted as high-risk industries are: nuclear power plants, energy utility plants, transportation systems (aircrafts, space shuttles, shipping), chemical plants, offshore installations, and large construction projects. Some of these organizations display outstanding safety records despite the trying conditions they are operating within. Such high reliability organizations (HRO) are required to handle complex, demanding technologies under hazardous conditions without causing major accidents (LaPorte & Consolini, 1991). Weick et al (1999) argue that HROs should be viewed as central to the mainstream organizational literature because they provide a unique window into organizational effectiveness under trying conditions. Scott (1994) also asks for a better integration of the study of high-risk organizations into the study of organizations in general. Following these recommendations, the relations between high-risk organizations and organizational effectiveness, organizational learning, or organizational knowledge should be explored in further depth.

Organizational redundancy is one such concept relating high-risk organizations with organizational knowledge, learning and efficiency. LaPorte and Consolini (1991) suggest that HROs achieve reliable performance by building organizational redundancy. They define organizational redundancy as overlapping competence in both a structural and cultural manner. The structural dimension includes possibility of direct observation, overlapping competence, tasks or responsibility. The cultural dimension includes capability and willingness to exchange information, provide feedback, and reconsider decisions made by one self and colleagues. Redundancy is also considered an important prerequisite for organizational knowledge. According to Nonaka & Takeuchi (1995) redundancy involves information that go beyond the immediate operational requirements of organizational members, and information overlap. Leading to both reliability and organizational knowledge, the study of redundancy seems important in the case of organizational knowledge in high-risk

industries. Results from an exploratory study of an offshore oil production platform indicate that operators and maintenance personnel may have established extensive organizational redundancy (Rosness et al, 2001). This was done through patterns of co-operation, level of staffing, competence level and organizational structure at the platform. The study furthermore displays a picture of staffing levels and organizational structures and cultures on Norwegian production platforms allowing for a considerable degree of organizational redundancy during the 1990s. Today, downsizing processes and low staffing levels might threaten organizational redundancy, and thus lead to increased risk. As Lawson (2001) puts it: "As organizational systems and technologies become more complex, removing organizational resources that facilitate monitoring and learning and adapting becomes not only short-sighted, but dangerous" (p. 127).

Requisite variety is another interesting concept in the crossing point between high-risk organizations and organizational knowledge. Requisite variety relates to high-risk organization because it involves the ability to cope with many contingencies. More specific, requisite variety is defined as internal diversity to match variety and complexity of the environment (Nonaka & Takeuchi, 1995), with heavy influence on organizational knowledge capabilities. Internal diversity may be interpreted as variation in backgrounds, perspectives, and solutions. Weick (1987) relates requisite variety to high-risk industries by arguing that accidents occur because the humans who operate and manage complex systems are themselves not sufficiently complex to sense and anticipate the problems generated by those systems. One way of preventing accidents from happening would then be to provide a better match between system complexity and human complexity. A team of divergent individuals has more requisite variety than a team of homogeneous individuals. Studies in high-risk industries have indicated that a lack of requisite variety may have influenced the organizations' abilities for sense making and learning (Carroll, 1995; Husemoen, 1997; Pedersen & Aase, 2001; Aase, 1998). Carroll (1995) refers to this as a solution-driven search for familiar answers to problems in nuclear power industry. A similar conclusion is drawn from studies in oil and gas industry, referring to a predefined and homogeneous engineering setting that induces organizational, cultural, and structural impediments to organizational knowledge (Pedersen & Aase, 2001).

Weick (1987) refers to the importance of information richness in high reliability systems (p. 115). Information richness is highest when people work face-to-face, and the richness

declines steadily as people move from face-to-face interaction to interaction by telephone, written personal communiqués (letters and memos), written formal communiqués (bulletins, documents), and numeric formal communiqués (computer printouts) (Daft & Lengel, 1984). High-risk industries involve system complexity, and rich media provide multiple cues and quick feedback, which are essential for complex issues but less essential for routine issues. Weick (1987) claims that too much richness introduces the inefficiencies of over-complication, and that too little media richness introduces the inaccuracy of over-simplification. Studies in the Norwegian oil and gas industry conclude that the engineering community develops model-based approaches to organizational knowledge (e.g. databases, written procedures) with low information richness (Aase, 1997; Wulff, 1997). According to Weick (1987), face-to-face communication in high-risk organizations is important in the context of the large number of engineers typically found in such organizations. He stereotypes engineers as 'smart people who don't talk'. If high reliability organizations need rich, dense talk to maintain complexity, then they may find it hard to generate this richness if talk is devalued or if people are unable to find substitutes for talk.

3. Learning constraints in high-risk industries

Already displaying the importance of organizational redundancy, requisite variety and information richness in high-risk industries, some of the learning constraints have accordingly been put on the agenda. Based on what we now know about high-risk industries, following questions are of current interest in the following discussion of learning constraints: Is it possible to achieve efficiency and reliability simultaneously? Do downsizing and outsourcing affect organizational redundancy and reliability? Is the requisite variety in traditional high-risk engineering communities sufficient to manage and solve complex learning tasks? Do rich media provide better conditions for reliability in high-risk industries than lean media?

Even if the literature shows evidence for a number of case studies documenting high reliability organizations (Weick et al, 1999), a direct causality between safety records and organizational knowledge abilities does not necessarily exist. At any rate, good safety records or not, high-risk industries are faced with a set of learning constraints based on their dependency on high reliability and their need for absence of major accidents. Many of these

constraints are due to high-risk organizations' inability to employ the common learning modes of exploitation and exploration (March, 1996). Exploitation involves the use and development of things already known, exploration involves the pursuit of new knowledge. High reliability literature cautions against exploration where trials can escalate in unexpected ways, leading to dangerous situations (Weick et al, 1999). Exploitation can also be difficult because systems are understood imperfectly and all possible failure modes have not yet occurred. High-risk organizations dependant on high reliability may therefore have unique problems in learning and understanding (Weick, 1987).

As mentioned in the requisite variety discussion, many high-risk organizations may experience difficulties in the available mental models or understandings of organizations, people, and technologies. Carroll (1998a) uses the term underlying logics to refer to linked assumptions and ways of thinking that give meaning to experience and guide inference and imagination (p. 700). Different logics arise from different occupational and hierarchical groups working on different problems in different ways. In his study of nuclear power plants and chemical process plants, Carroll found that the level of complexity and tight coupling among problems and issues required more comprehensive logics than those typically employed. There was a tendency towards using logics comprised by anticipation, concrete issues, and a fixing orientation. A more comprehensive set of logics would also include resilience, abstract issues, and a learning orientation. Carroll claims that enhanced learning in high-risk industries requires ways to broaden and bring together disparate logics.

Continuing the debate on exploitation and exploration modes of learning in high-risk organizations, organizational learning literature also calls for a high degree of experimentation and trial-and-error processes for ideal learning (Hedberg, 1981; Levitt & March, 1988; Vogt, 1995; Kim, 1995). Several contributions within organization theory have also emphasized the value of learning from failures, and assess them as more important than the success stories (Petroski, 1985, 1994; Sitkin, 1992; Herriott et al., 1985; Weick et al., 1999). As already mentioned, learning from failures, mistakes and trial-and-error will often not be tolerated in high-risk industries due to the potentially catastrophic outcome associated with mistakes. The Three Mile Island accident (nuclear industry) is an example of a learning failure where ignorance of near misses at other plants and previous similar errors was the dominant view in the organization. To overcome these learning constraints, high-risk organizations must learn as much as possible from minor precursor problems, transfer

learning effectively across organizations, and improve their processes without trial-and-error processes to stimulate learning (Carroll, 1995). High-risk industries must then to a large extent concentrate on proactive learning approaches.

Proactive learning approaches mean to create substitutes for trial-and-error, and can include issues of simulation, incident review, self-assessment, imagination, vicarious experiences, stories, and other symbolic representation (Weick, 1987; Carroll, 1995). Few studies seem to address such proactive learning approaches within high-risk industries, and even more important, the ability such organizations have to develop these approaches. Carroll (1995) studied incident review processes in nuclear power plants. The incident reviews were meant to be a preventive means for learning from minor precursor problems before they escalated into more serious accidents, involving workers at all levels conducting formal analyses in review teams. The study showed evidence of cognitive and cultural assumptions limiting the event reviews (root cause seduction, sharp-end focus, solution-driven search, account acceptability). In an intervention study in an engineering department in the Norwegian oil and gas industry, proactive approaches called learning sessions and case study sessions were developed and introduced (Pedersen & Aase, 2001). The study documented that the project-based engineering setting induced organizational, cultural, and structural learning constraints affecting the functioning of the two learning approaches. Organizational constraints came in forms of insufficient management involvement, lack of commitment, and priority. Cultural constraints came in forms of reification, codification, and an epistemology of possession. Structural constraints came in forms of employee turnover, discipline-based organizing, and time pressure.

Bearing the complex picture of high-risk characteristics and learning constraints in mind, the remaining parts of the paper will present learning approaches to safety developed in respectively the model-based and the human inquiry based perspective.

4. Model-based approaches to safety

The basic assumption of modern safety philosophy in high-risk industries is that accidents are preventable. Many companies and organizations work according to a so-called 'zero philosophy', with zero accidents and injuries as the overall objective. Within this philosophy, accidents are preventable through effective feedback control, often based on an understanding that safety management is a logical process aimed at continuous risk reduction. The safety management process is divided into discrete steps with slightly different number of steps and terms to describe the steps, dependant on the different management concepts in use. In general, the safety management cycles all contain phases like 'acquisition of information', 'analyses/ decisions', 'implementing measures', and 'evaluations'. Successful safety management is dependent on a continuous flow of information between the various steps (Aase & Ringstad, 1998; 1999).

The assumptions of safety management within high-risk industries are also influenced by former and present safety research. Traditionally, safety has been conceptualized as an engineering specialty, and most of the literature on safety focuses on equipment and other technical concerns (Carroll, 1998a). Empirical safety research has typically been based on statistical, epidemiological analyses of accidents and incidents, and the level of safety attained has been measured by LTI rates (Loss Time Injuries) and fatalities (Hovden, 2000). The statistical approach is often justified by reference to the somewhat disputed assumption of the 'iceberg theory' postulating a close relationship between near misses, accidents and disasters.

In line with the proactive learning perspective based on incidents and near misses, high-risk industries of several kinds (oil and gas industry, civil aviation industry, transportation industry, shipping and shipbuilding industry) utilize sophisticated systems for accident recording and analyses (Ringstad, 2002). The use of such systems is regarded as an indication of a resourceful and mature safety management policy, and in the Norwegian oil and gas industry an accident reporting system is mandatory. These accident/ incident information systems are thus designed to use experience-based information or historical data to improve working conditions and safety level. Some studies have been conducted to address the impact of accident/ incident information systems on safety and learning (Ringstad, 1998; Carroll, 1995; 1998a; Aase, 1997). A common point is a tendency towards biases in the reporting procedures. Results document that human errors are not reported to the same extent as technology-driven incidents. Extensive details on equipment and human issues may be found, but very little on organizational, programmatic, and cultural issues. Reason (1991) opposes

the role of accident/ incident reporting systems, referring to the information they provide as 'both too little and too late' for the long-term purpose of effective safety management.

Gherardi & Nicolini (2000) have developed two characteristics of traditional approaches to safety during the past ten years: The 'technical route to safety' and the 'normative route to safety'. The technical route to safety considers safety to be a property of technical systems that is objectified in 'safe' technologies and artifacts. Risk analyses have become the central approach within this paradigm. The main feature of this approach is that it transfers the burden of decision making in conditions of uncertainty from the individual to the scientific community, delegating to safety engineers the responsibility for determining the criteria to be used (p. 8). The basic assumption behind probabilistic safety analyses is that events are enumerable, predictable and additive. There is a strong emphasis on the immediately measurable aspects of risk. In most cases of failures or accidents, these analyses do not mirror the actual situation. Research show that serious accidents nearly always involve being outside the 'design basis' or modeling assumptions of the safety analyses (Carroll, 1998a; Rasmussen, 1990). Risk analyses have been subject for criticism as to the significant role they have played in considering risk in substantially neutral and detached terms as an 'objective' aspect of reality (Gherardi & Nicolini, 2000).

The normative route to safety views safety as the outcome of the application of rules and regulations that prescribe 'safe' individual and collective behaviors (Gherardi & Nicolini, 2000). In complex, high-risk industries documentation has traditionally been seen as a vital element in development, design and operation, not only within the safety area. Documentation is an important part of managing the business. Requirements and procedures are developed to give the organization members guidelines and working methods, and to give management a way of controlling company activities, including safety issues. Within the safety area, high-risk organizations are additionally subject to strict standardization, documentation and regulation demands from the authorities. An internal efficiency project in a Norwegian oil company showed that about 800 different requirement and procedure handbooks existed within the exploration and production area (Aase, 1998). After a huge restructuring and efficiency process, 18 so-called functional handbooks remained. Empirical results found that after implementation of the new handbooks, more than 50% did not know anything about the content of the handbook of health, safety and environment. The above example indicates that safe behavior cannot solely depend on rules and regulations.

Included in both technical and normative approaches to safety, training has played an important role in preventing industrial accidents in organizations. Safety training has often consisted of safety introduction programs, outlining of safety and emergency procedures, safety videos, etc (Collinson, 1999). These forms of training are often based on conventional scholastic models where abstract knowledge is conveyed through educational texts and rules of behavior. Taken together with the rationalization perspective of the technical route to safety, training is then seen as an attempt to codify and regulate the discretionary aspects of work (Gherardi & Nicolini, 2000).

During the past ten years, high-risk industries themselves have focused heavily on what we can call the 'cultural route to safety'. This has also been supported by safety research encouraging organizations to "*create a positive safety culture and an open learning atmosphere in which mistakes, errors and near-misses could be discussed openly and without fear of blame or recrimination*" (Turner, 1995, p. 325). To create a safety culture has turned out to be easier said than done. Despite a considerable industrial and academic focus, Reason describes the following situation in 1997: "*Few phrases occur more frequently in discussions about hazardous technologies than safety culture. Few things are so sought after and yet so little understood*" (Reason, 1997, p. 191). Safety culture has been approached in different ways, but traditionally means like safety campaigns, management involvement, information channels, training, etc. have been included in the efforts. Or as Collinson (1999) reports in his study of a North Sea oil installation, the safety culture of the case study company, as the management termed it, was built around the 'seven elements' of: sound design and engineering, quality materials and equipment, high standards of construction, fully trained and responsible personnel, effective supervision and procedures, a clearly defined and regulatory framework, and rigorous inspection and maintenance (p. 583). Research-wise, there have been numerous attempts on developing measurement tools for safety culture or safety climate (e.g. Cox & Flin, 1998; Flin et al, 2000; Cooper, 2000). Such measurement attempts tend to focus upon individual attitudes and behavior, not addressing the anthropological origins of the culture concepts (Pidgeon, 1998).

Recent contributions within the literature apply a more practice-based approach to safety. According to Gherardi & Nicolini (2000), safety is viewed as a situated practice emerging from a collective process involving people, technologies, and textual and symbolic forms (p.

10). The authors document how issues like narratives, conversations, and social participation generate and affect the safety knowledge. Carroll (1998b) also pictures safety as an ongoing cultural process, with learning, self-assessment, and collective discussions as key issues. This leads us into the less explored area of human inquiry based approaches to safety.

5. Human inquiry based approaches to safety?

Throughout the paper we have documented a general tendency towards developing model-based approaches to organizational knowledge in complex, high-risk organizations. We have described the nature of high-risk industries as a 'hostile' learning environment. Simultaneously, we are messengers of a more practice-based view, or a human inquiry based perspective, on safety and organizational knowledge in high-risk industries. We argue that it is not safety as a specific topic or subject that should be learned, but safe work practices. Given the learning conditions of high-risk industries, is this a 'mission impossible'?

Few studies have been designed with the aim of investigating alternative learning approaches, based on a human inquiry perspective, in high-risk environments. We have called attention to certain issues that seem inevitable in developing alternative approaches to the learning of safe work practices. One of the premises of such approaches must be the ability to substitute trial-and-error learning (Weick, 1987). Another premise is the underlying belief that safety knowledge is a collective competence or culture developed in communities of practice (Gherardi & Nicolini, 2000). Important issues mentioned throughout the paper have been imagination, learning from failures, exploration or experimentation, proactive learning processes, requisite variety, stories, and self-assessment. Below, some of these issues are further elaborated to assess the possibility of building such elements of human inquiry into the learning of safe work practices in high-risk industries.

5.1 Imaginations and improvisations

Proactive abilities are highly necessary in the accident preventive work of high-risk industries. By proactive abilities we mean the capacity or creativity an organization has to think in advance in order to substitute trial-and-error learning. 'To think the unthinkable' is a

characteristic of proactive abilities. An organization's ability to imagine and improvise will affect its proactive capability. Imagination is thinking about what 'could have been' or what 'might have been'.

Much of today's proactive safety work in high-risk industries is based on an imagination philosophy. Learning and feedback from near misses or incidents, simulations, and emergency preparedness are examples of safety activities based on imagination. Morris & Moore (2000) have studied how pilots learn from imagined might-have-been scenarios (counterfactual thinking) or close calls within the aviation industry. They analyzed the narrative descriptions made by pilots experiencing near accidents, and found that 35% of the descriptions contained 'might have been' thoughts. For more severe incidents, the number was higher. Whether these aspects of counterfactual thinking would lead to performance-promoting lessons for the pilots would depend on several factors. One of these factors was the degree of upward comparisons of reality to better possible alternatives of the type "If I had understood the controller's words accurately, I wouldn't have initiated the inappropriate landing attempt". Another factor was the degree of self-focused thoughts of the type "What I might have done better" as opposed to other-focused thoughts of the type "What someone else might have done better".

In the oil and gas industry, analyses of incidents and near misses have been a reality for some time already. In an analysis of a sample of 2000 corrective actions or risk reducing measures (learning and improvement issues) suggested in the written incident reports, three main categories were found (Aase & Ringstad, 1998). Information hand-over of the type "Relevant information about the danger of slippery floors and falling" and "Inform at safety meeting" included 37% of the actions. Immediate and specific repairs of the type "Changed hose clips and installed safety wire" and "The loose bolt was tightened" included 40% of the actions. Changes in procedures or technology of the type "Better follow-up of routines for coordination and communication" and "Suggest long-term solution after inspection" included 12% of the actions analyzed. Results showed that there were a modest number of corrective actions leading to deeper organizational knowledge or learning processes, and that incident descriptions to a little extent contained imaginary or creative thoughts to create performance-promoting lessons. Even if several of today's safety approaches include elements of imagination, these approaches are sometimes reduced to more rational or solution-driven means. Corrective actions of the type 'information hand-over' and 'immediate and specific

repairs' might form a starting point for learning processes that are not reflected in the written reports. This requires further research focusing on the existing processes of informal learning in high-risk industries, or the development of learning processes with more distinct elements of imagination or improvisation.

To use imagination in a human inquiry perspective, approaches should to a larger extent include elements of simulations, role-playing, improvisational players, and spontaneous behavior (Weick, 2001) to foster creativity and collective competence in preventing accidents and developing safe work practices. This is especially important in the case of requisite variety. We have claimed that high-risk industries, e.g. the offshore oil industry, are characterized by homogeneity or low requisite variety. To deal with complexity and interdependencies high-risk organizations are dependent on higher degree of requisite variety. The role of imagination and improvisation to improve requisite variety in high-risk industries should therefore be subject for further studies.

5.2 Intelligent failure promotion

As noted earlier in the paper, failure is seen as a better learning enabler than success. Weick et al. argue that effective high-risk organizations organize socially around failure rather than success (1999). Sitkin (1992) advocates this perspective in his influential theoretical work on learning through failure. He presents a framework for failures to be intelligent and act as an essential prerequisite for organizational learning and adaptation. Organizational conditions that facilitate intelligent failure are: (a) to increase the focus on process rather than outcomes, (b) to legitimate intelligent failure, (c) to engender and sustain individual commitment to intelligent failure through organizational culture and design, and (d) to emphasize failure management systems rather than individual failure (p. 557). At first glance, the number of pitfalls in achieving these conditions is numerous in the case of high-risk industries. For example will a focus on process rather than outcome outplay efficiency in advantage of reliability. And the legitimacy of failure might lead to uncontrollable trial-and-error learning. Nevertheless, the literature on high reliability organizations reports that the preoccupation with failure is what gives these organizations much of their distinctive quality (Weick et al, 1999). Organizations that have fewer accidents than expected balance the tension between rewarding efficiency and rewarding reliability (Roberts & Bea, 2001).

In an intelligent failure promotion approach spaces of non-punishability and incentives to encourage a more freely discussion and comparison of accidents should be defined. All failures should be viewed as windows on the health of the system, near failures should be analyzed and discussed, and the liabilities of success should be focused. In a human inquiry approach to safety, issues of failure promotion should be integrated in practice-based approaches or arenas.

5.3 Stories

People think narratively rather than argumentatively or paradigmatically (Weick, 2001). This means that human beings learn best from stories. In organizations people have been telling stories for centuries, but the value of sharing information and knowledge in a natural way through stories has not been realized until recently. Several contributions within organizational knowledge and learning are now addressing stories and histories as vehicles for knowledge sharing, and as catalysts for organizational learning (Davenport & Prusak, 1998; Denning, 2000; Kaye & Jacobson, 1999; Kleiner & Roth, 1997). The authors provide managerial guidance and different sets of criteria for how storytelling can be promoted and addressed in organizations. Few empirical studies on organizations as storytelling systems have been published since Orr's (1990) well-known study of the importance of stories in the knowledge exchange within the community of practice of copier repairmen. One exception is Boje (1991) who studied story performance in an office-supply firm. His results supported a theory of organization as a collective storytelling system. The performance of stories was a key part of members' sense making and a means to allow them to supplement individual memories with institutional memory.

Paulsen (2001) uses a story to show how stories differ from the most common pedagogical method of rational argumentation.

> "A chemical process plant used a very powerful acid in their production. This acid was so strong that putting your finger in it would make your finger disappear. The acid was stored on suitable barrels. These barrels had to be transported from the storage room to the production line. Production workers carried out the operation. They were instructed to wear safety protective equipment. But the workers did not care to wear the equipment because it was easier to perform the operation without. The safety manager had observed this, and recited the issue several times. He had also written a circular memo explaining the dangers in handling

> the acid. Despite this, the workers continued to perform the operation without safety equipment. The rational arguments did not affect their behavior. The safety manager realized that he had to think otherwise. He called for a meeting without any agenda. In the middle of the meeting room he placed a small barrel containing the current acid. Without further explanation he asked the participants to place themselves in a circle around the barrel. With everybody in place he preceded to the barrel, dropping a grilled chicken into the acid. The chicken with skin and bone dissolved in the course of seconds, completely disappearing. The situation was an intense learning experience for the participants. But most important, the participants passed the story of the chicken on to other workers. And they started wearing safety protective equipment. The story managed what circular memo's and procedures did not".

Within high-risk industries, an organization that values stories, storytellers, and storytelling will be more reliable than a system that derogates these substitutes of trial-and-error (Weick, 1987). Stories coordinate, register, summarize, and allow for reconstruction of scenarios that are too complex for logical linear summaries to preserve, and they hold the potential to enhance requisite variety (p. 125). Furthermore, narrative skills are important in high-risk organizations because stories organize know-how, tacit knowledge, nuance, sequence, multiple causation, means-end relations, and consequences into a memorable plot (Weick & Roberts, 1993). Further research should be directed at whether storytelling is an integral part of today's safety practices in high-risk industries, or how stories can be an element in future safety efforts.

5.4 Collective training

Results from research on high reliability organizations indicate that organizations that have fewer accidents are those that teach their people how to recognize and respond to a variety of problems (Roberts & Bea, 2001). In addition to teaching people how to react to specific situations, even more important is the training on how to respond to situations that are not reported in the training manuals (p. 73). Roberts & Bea refer to operators at a nuclear power plant working their regular shifts three weeks every month, while the fourth week is purposed to training. Training during this week is intentionally designed to present a wide range of unusual and potentially dangerous scenarios, and provides a break from the anticipated smooth operation of the nuclear reactor for the operators. As we see, issues of imagination

and improvisation are integrated in the training, keeping the operators alert to things that can go wrong. This reinforces the fact that an organization needs to know 'what it doesn't know' to keep a catastrophe from occurring.

Using a human inquiry perspective training should include a collective element based on active participation, action learning or other participatory forms of training (Gherardi & Nicolini, 2000). This means that safety should be viewed as a competence developed in communities of practice. People tend to form relations or communities of practice that are enriching and meaningful and help them fulfill the requirements of their job (Brown & Duguid, 1991; Wenger & Snyder, 2000; Wenger, 1998). Safe work practices are thus learned through the display and observation of action. The members of a community learn safe work practices by participating in the community's present and past practices, just as much as they do from their education and traditional training methods. The narratives that circulate in a community of practice both transmit what is safe or dangerous and construct a collective identity (Gherardi & Nicolini, 2000: p. 12). In building collective training based on communities of practice, dialogue is a key issue. Isaacs (1993) defines dialogue as "sustained collective inquiry into the processes, assumptions, and certainties that compose everyday experience" (p. 25). By means of dialogue, fundamental assumptions, differences of opinion and defenses can be revealed in order to understand why they exist and gain new insight. Dialogue requires the ability and the will to listen with an open mind and reflect upon the information given, and to engage in a collective process of inquiry.

5.5 Case study sessions or problem investigation teams

Case study sessions are group-based arenas for dialogue and discussions (Pedersen & Aase, 2001). The aim is to form a basis for informal information exchange and learning, and to utilize good and bad experiences from specific working processes, technological issues, projects or activities. A research facilitated intervention project was carried out in an engineering department in a Norwegian oil company to develop and implement case study sessions. The project included activities like 'away days', kick-off meetings, champion sessions, learning sessions, and case study sessions. The case study sessions were led by a champion with comprehensive knowledge of the case at hand, and included participatory activities considering a variety of aspects at the core of the case (project planning, efficiency, profitability, best technical solution, time schedule, collaboration and coordination with

relevant others, use of former experience, use of relevant competence, and degree of well-being and social support among project members). Participation in the case study was voluntary, but the case study champion made considerable efforts to include all parties relevant to the subject at hand, including employees from operations and from suppliers. Participants valued the case study sessions positively:

> *"During the session, information about the offshore installation that I didn't know about was revealed. Especially the history behind how things are today. This is important to know in order to understand how things work and should be changed. This is the kind of information you don't find written anywhere"*
>
> *"Apart from the time pressure, I found the case studies to be useful. You get more input at the same time, and can discuss the cases at a multi-discipline level. Everybody can participate, and this is actually the only occasion we have had to do this".*

The project also revealed a number of learning constraints in the project-based engineering setting, as reported earlier in this paper. Despite this, valuable elements (active participation, cross-disciplinary discussions, story-telling) for organizational knowledge were created during the case study sessions.

The case study sessions have some similar aspects with problem investigation teams (Carroll et al, 2001) in nuclear power industry. Problem investigations are part of a corrective action program, and teams are created to handle the most persistent, casually ambiguous, and organizationally complex problems. The problem investigation teams use interviews, physical inspection, and document reviews to examine the undesirable events or trends, and to draw lessons about underlying causes and ways to prevent future problems (p. 2). In studying 27 problem investigation teams at three nuclear power plants, Carroll et al. found that good investigations were linked with more team training and experience, less need for closure, and more diversity of work experience. Negotiating reports with management and other boundary-spanning practices contributed to distinct knowledge reservoirs and influenced learning. In analyzing the written investigation reports, the researchers found disappointing depth and creativity with no evidence of actions that could change deeper structures and enact deeper learning processes (confer discussion in section 5.1 on lack of imaginary thoughts in written incident reports: Morris & Moore, 2000; Aase & Ringstad, 1998).

6. Conclusions and further research

This paper has shown that specific characteristics of high-risk industries influence the learning conditions of these organizations, their proactive abilities, and their repertoire of possible learning approaches. Empirical studies have documented the tendency towards developing model-based approaches to organizational knowledge and learning within safety in high-risk organizations. This tendency might be caused directly by the hostile learning environment of these organizations, or by other, yet unknown, reasons. Research also proves the inadequacies of such model-based learning approaches. Organizational knowledge and learning should include elements from a human inquiry perspective, emphasizing collective processes for meaning making, experimentation, dialogue, and exchange of tacit knowledge. Our aim has been to visualize some of these human inquiry elements, in order to assess their applicability in high-risk organizations. Is it possible to include alternative learning approaches based on a human inquiry perspective in these organizations, given the nature of high-risk industries? Or should these industries hold on to regulated and formalized learning approaches due to the inevitable probability of major accidents?

By using concepts like complexity, interdependencies, organizational redundancy, requisite variety, and information richness, the relationship between high-risk organization literature and organization theory in general is visualized throughout the paper. Our assertion is that any organization facing an increasingly complex environment, efficiency demands, and a growing number of interdependencies, can experience the same types of learning constraints that do high-risk organizations. No organization is immune from errors that can have far-reaching consequences. Therefore, the study of organizational knowledge in high-risk industries is important to gain expertise on how learning processes can be developed under trying conditions. At some point, any organization might be faced with the demand of developing alternatives to trial-and-error learning.

Already fifteen years ago, Weick claimed that we had thought about reliability in conventional ways using ideas of structure, training, and redundancy, and seemed to be up against some limits in where those ideas could take us (1987, p. 126). In the wake of this statement, the literature on high reliability organizations was established, focusing on how such organizations could minimize the frequency and severity of accidents or disasters. Some

of the recommendations were already then focusing on organizing for high reliability by creating processes of collective mindfulness. These processes should be based on a preoccupation with failure, an increase in level of requisite variety, and the development of substitutes for trial-and-error learning by using elements from imagination, storytelling, simulation, etc.

Future research on learning in high-risk industries should be concerned with the issues raised above. The research agenda should be two-folded. First, studies generating knowledge on the existing informal learning approaches in high-risk industries are required. Second, studies on the development and testing of new learning approaches based on a human inquiry perspective are necessary. Based on this research agenda, a set of possible future research questions can be deducted:

- To what extent do elements of human inquiry (informal learning approaches) already exist in high-risk industries?
- How are elements of imagination, storytelling, case studies, or collective training included in the learning of safe work practices in high-risk industries?
- Is it possible to adapt or develop human inquiry approaches to organizational knowledge and learning given the learning conditions of high-risk industries?
- Will human inquiry approaches to organizational knowledge and learning lead to new knowledge and safe work practices in high-risk industries?

These questions only represent a few alternatives to a comprehensive and highly necessary future research area.

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