Safety and Reliability – Safe Societies in a Changing World – Haugen et al. (Eds)

Field operations in the high arctic—experienced feedback and tacit knowledge as key tools for safety management

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ABSTRACT: The paper demonstrates the importance of tacit knowledge to cope with various situations during field work in the high arctic. Two cases from field work at the University Center in Svalbard (UNIS) are shown to exemplify this: one boat trip and one snow mobile trip with researchers and students. Successful field operations depend heavily on technicians from the UNIS Field Safety Section that have the responsibility to assist in the planning and execution of every type of field work. Due to rapidly changing conditions, local variations, extreme weather conditions, lack of access to infrastructure and communication, successful safety performance is accomplished by individual's ability to adapt to situations. The paper demonstrates that this ability to a large extent is a function of the tacit knowledge of the technicians. To improve the tacit knowledge of each technicians, systems and practices of experience feedback must be run to ensure individual and organizational learning from both failures as well as successes. This is in particular important in systems with great variability in climatic conditions and systems with organizational changes.

1 INTRODUCTION

The University Centre in Svalbard (UNIS) has been operating in Longyearbyen, Svalbard since 1993. Longyearbyen is a small town located on the west side of Spitsbergen, a part of the Svalbard archipelago in the high arctic at 78 degrees north. UNIS educates more than 800 students and supports close to one hundred research projects on an annual basis. In total UNIS has close to 12 000 field days per year. The education and research is field based and the season lasts from January to December.

Operations in the high arctic prove to be challenging. Challenges encountered include, but are not limited to: lack of infrastructure, harsh and variable weather, darkness, and rapidly changing natural hazards. These are conditions that have to be handled from day to day to ensure safe operations for students and scientists.

In the last five years natural hazards have been changing at such an increased rate (e.g. avalanche danger, melting sea ice, high levels of precipitation, rapid fluctuations in air temperature etc.). For UNIS this implies that established operational procedures based from many years of experience are no longer valid. The practitioners responsible for planning and guiding students and scientists in the field often experience that the plan deviates from the performance. They have to choose deviation "constantly" to maintain a safe performance of the activity. A challenge is thus to have a system or process that secures feedback to the decision makers.

To keep up with the changing risk picture, experienced feedback and tacit knowledge are getting more and more important to maintain safety management and safe operations.

The purpose of the paper is to exemplify how experienced feedback and tactic knowledge are used to manage safety for operations in the high arctic and discuss how experience feedback can ensure organizational learning for field operations.

2 EXPERIENCE FEEDBACK

Safety management is based on the principle of experience feedback, i.e. the process by which information about the results of an activity is fed back to decision makers as new input to modify and improve subsequent activities (Kjellén and Albrechtsen, 2017). Kamsu Foguem et al. (2008) have a similar interpretation: experience feedback is a process whereby experience at an operational, tactical or strategic level is disseminated in such a way that the knowledge is used to improve the organization's performance.

The purpose is to use information about experienced or expected safety performance as a basis for decisions that prevent accidents and reduce accident risk.

Experience feedback is based on principles from quality management such as Juran (1989) persistent feedback control and Deming's (1993) cycle. Kjellén and Albrechtsen (2017) present a safety information system based on principles of experience feedback that consist of collection of data about experienced and expected safety performance; analysis and storage of the data; distribution of analyzed data to decision-makers; and decision-making and implantation of safety measures. This system facilitates systematically improvement of safety based on experiences (incidents, non-conformities, observations, etc.); identification of current performance (inspections, audits); and excepted safety performance and challenges (risk assessments).

Another important principle of experience feedback is organizational learning and knowledge sharing. The process of organizational learning involves an organizational unit changing itself or its knowledge base as a result of experience (Cyert & March, 1963). The unit can learn directly from its own experiences, or from the experiences of other units (Levitt & March, 1988). Argyris and Schön (1996) claim that organizations learn only if the product is a change in behavior and governing variables in the organization.

Although the literature differs between individual and organizational learning, there is a clear relationship between the two (Crossan et. al, 1999). Nonaka and Takeuchi (1995) demonstrates how transitions of tacit and explicit knowledge lead

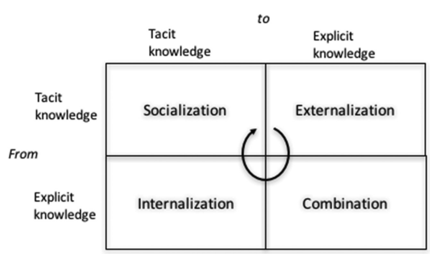

Figure 1. Knowledge creation in organizations (Nonaka and Takeuchi (1995).

to organizational knowledge (Figure 1). Through these processes, knowledge is converted from individual knowledge to shared knowledge that can be utilised by the whole organisation. The transitions are continuous processes that lead to a learning spiral. Nonaka & Takeuchi (1995) propose four basic processes whereby knowledge is converted:

- Externalisation takes place when tacit knowledge is made explicit, for example when an unwanted occurrence is observed and reported by a worker at the sharp end.
- Combination takes place when explicit knowledge is combined with other explicit knowledge, for example when a reported unwanted occurrence is compared with other reported unwanted occurrences in an effort to identify similarities.
- Internalisation takes place when explicit knowledge becomes tacit knowledge. The point is to see the importance of making practical use of knowledge through converting the explicit to practical, effective and correct actions.
- Socialisation takes place when tacit knowledge is spread as tacit knowledge to other members of the organisation, who learn over time through seeing what others do.

Principles of organizational learning implies that safety management based by experience feedback is dependent on both formal and informal processes of knowledge sharing among practitioners, safety staff and managers.

3 SAFETY CHALLENGES IN FIELD OPERATIONS AT THE UNIVERSITY CENTRE IN SVALBARD

Every person going through the UNIS system expects access to teaching, learning or research in the field. Safety technicians at UNIS have the responsibility to assist in the planning and execution of every type of field work. This includes the safe transport of groups to their desired field locations, and then further technical assistance and general safety at the field site. Safety technicians at UNIS benefit from the experience of years of living and working in the Arctic. This includes hundreds of hours of work in the field on an annual basis.

At UNIS there are two distinct field seasons. Winter field season normally runs from January-May, while summer field season extends from June-October. November and December are typically slower, due to lack of snow and light.

Winter field season is characterized by snow mobile travel. Other forms of transportation may include travel by beltwagon or larger sea going vessels. Typical hazards encountered during winter season include: snow mobile driving, avalanche terrain, sea ice, glaciers, harsh weather conditions, and polar bear encounters.

Field operations in the summer season is mainly done by boat travel. A variety of vessels are used including: zodiacs, polar circles, tourist boats and large cruise vessels. Typical hazards encountered during summer season include: harsh weather, rough ocean conditions, camp challenges, polar bear encounters, and hazards encountered when travelling in steep mountainous terrain.

The top priority in both winter and summer field seasons for the technicians is to ensure the group has safe transportation from Longyearbyen to their field location. In winter season this is controlling a group of 10–30 students and teachers on snow mobiles as they drive through variable terrain to their destination. In summer this is transporting up to 12 students and teachers at a time by polar circle to their destination.

Ideally the technicians should only operate under favorable conditions, where there are few hazards and thus low risk. Due to the environment and related hazards and challenges, all activities involve some kind of risk, and the plan often deviates from what is expected.

Two examples will be presented which illustrate the challenges associated with field travel in both winter and summer

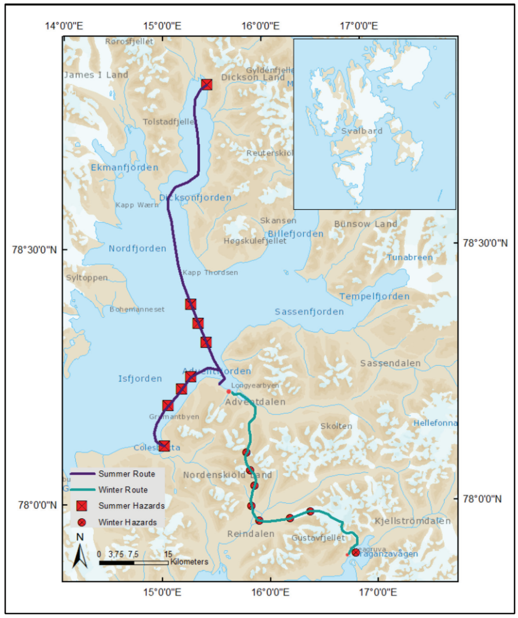

Figure 2. Map showing the routes described in the following tasks. Summer hazards are where shallows and rough seas are normally encountered. Winter hazards are where avalanche, glacier, sea ice and open water hazards are normally encountered. Basemaps © Norwegian Polar Institute.

3.1 *Case 1: Boat travel, summer season*

The objective of the field travel was to drop off one group to Colesbukta, drop off camp equipment and perform water sampling in Dicksonfjorden, see map in Figure 2. The two trips were originally scheduled to take place on different days, but this had to be changed when an attempt to drop off the first group in Colesbukta the day prior was unsuccessful. Technician A had taken three scientists, plus a boat full of field equipment towards Colesbukta the previous afternoon. The group had traveled for approximately one hour in bad conditions, heading straight into the oncoming waves which were crashing over the bow of the boat at a height of over two meters. The technician decided to turn around for several reasons:

– If the technician maintained the same speed, an hour long round trip would have taken two to four hours in conditions which were not supposed to improve
– The wind direction was not favourable for landing in the desired location
– The scientists had a lot of heavy equipment which would take a long time to unload
– The desired drop off point was extremely shallow, with lots of known objects in the water. With heavy waves and wind, chances of either grounding the boat, or hitting the propeller/engine on an object were increased
– The boat was heavy and had a broken anchor winch, making it not ideal for shore landings, especially with the given conditions

If the technician only encountered one of the before-mentioned factors, the trip would probably have been completed. A combination of all of the factors, which the technician was able to identify during the trip, forced the decision to turn around. There was no protocol for this, but due to past experiences the technician was able to determine that in this particular situation, the risk was not worth the potential consequences.

The next day the winds and sea had calmed making it realistic to complete both trips. Due to a combination of factors it was decided that two technicians and two boats were needed to make this a successful operation. A request was made by Technician A to Technician B for assistance. Factors which were considered for this trip included:

– Colesbukta and Dicksonfjorden are in opposite directions, so if only one boat went, the trip would take a significantly longer amount of time
– The drop-off spot for the camp in Dicksonfjorden is dependent on tides. A lot of gear needed

to be unloaded which is time sensitive in order to not ground the boat
- The boat going first to Dicksonfjorden needed to pick up scientists from the camp for sampling
- Wind was coming from east, making the travel to Dicksonfjorden fine, but more challenging on the way back to Longyearbyen when heading directly into the wind

The plan was then executed safely and successfully. The two boats left at the same time, with Boat B heading first to Colesbukta to drop off scientists and gear, and then bring the rest of the gear to Dicksonfjorden to meet Boat A in time to drop off equipment before the tide started falling. Boat A went straight to Dicksonfjorden and was able to complete the sampling and drop off the other equipment. Boat A and Boat B were then able to drive back to Longyearbyen from Dicksonfjorden together, which was optimal because the winds began to pick up creating unfavorable conditions for driving alone. Boat B has a covered cabin, making it more favorable for driving in big waves. Boat A could then drive in the wake of Boat B, as to not get as many waves into the boat on the way back to Longyearbyen.

This task ended successfully for several reasons. The two technicians had combined experience from driving boats in Isfjorden. They both knew the challenges with landing in the two areas, and were able to understand the implications that the weather conditions and tides would have on the locations they needed to get to and tasks they needed to complete. Flexibility played a huge part in that both technicians were willing to change plans when it proved necessary in order to complete a safe and successful trip. The challenges and potential hazards encountered during this scenario are not uncommon or unknown. Shallows, tides, waves, wind, boat problems, etc., are all encountered by boat drivers in Svalbard. The challenges can be anticipated, but only the knowledge one needs to be equipped to deal with them, and to operate around them are only gained through experience.

Figure 3. Example of vessel used during field trips, UNIS Polaris beached.

3.2 *Case 2: Snow mobile travel, winter season*

The objective of the field travel was to transport a group of students and professors from Longyearbyen to Svea (a small mining settlement located 60 km away from Longyearbyen) in early February by snow mobiles. Travel between Longyearbyen and Svea is common during the winter and spring months by snow mobile. Transporting a group of up to 25 students and professors to do work on the sea ice close to Svea is normally not challenging. However, in recent years, Svalbard has experienced more precipitation, higher temperatures and less sea ice. This leads to more challenging conditions for winter field work. The technicians anticipated the following risk factors for this particular task:

- 25 people with little to no snow mobile experience must drive over 60 km through challenging conditions
- Driving through avalanche terrain
- Driving in places with open water
- Driving over terrain which is icy and rocky
- Driving over glaciers with crevasses
- Working on sea ice

Therefore, special precautions had to be taken, and here it is the job of the technicians to use their knowledge and expertise to ensure the group can travel and work safely in Svea. One should always expect and be prepared to encounter hazards doing this kind of work, but in this particular situation there were several risk factors which needed special attention from the technicians to ensure safe and successful travel:

- The season up to this point had brought unusual conditions which included: a lot of snow, followed by heavy rain and temperatures up to +7°C. Temperatures then quickly fell to well below 0°C.
- The normal route to Svea includes traveling through narrow valleys surrounded by steep mountains which leads to both avalanche hazards and water hazards
- The route also includes travel across a wide open valley which is vulnerable to wind which can blow all of the snow away leading to icy and rocky conditions
- The route includes a glacier crossing which creates a potential crevasse hazard
- Due to the decreased activity in Svea, the route which is normally well maintained is much more unknown and unpredictable

– Sea ice which is normally forms close to Svea is affected by warmer air and sea temperatures. Extra precaution must be taken when working on this ice.

Instead of the normal procedure of sending out one technician to follow the group as would be necessary, several scouting trips were undertaken in order to identify all of the possible hazards the group might encounter, and to confirm that safe travel was possible. Three separate scouting trips were completed until the technicians were satisfied that they were comfortable sending the group through the terrain and had identified all possible hazards and deemed them manageable for the group. The technicians identified open water, avalanche conditions, blue ice and rocks. They were able to deviate slightly from the normal route, in order to find a route which was as safe as possible for the students and staff.

On the day when the students and staff were supposed to travel to Svea, two technicians joined to ensure safe travel. The trip was completed successfully and the students and staff were able to do their work in Svea.

4 DISCUSSION

4.1 *Adaptation and flexibility*

Both field trip examples described in the previous section were successful in terms of safety because the technicians were able to anticipate the risks of the trips and thus adapt to the situation of the trips. Rankin et al. (2014) present a framework for understanding coping mechanism (adaptions) to respond to variations in a dynamic environment, see Figure 4. Adaptions are a function of 1) objectives, i.e. the outcome that the adaption aims at achieving and is related to identifying demands, pressures and conflicting goals; 2) the context in which the adaption is carried out; and 3) necessary resources and conditions for successful implementations of the coping mechanism, including both "hard" and "soft" conditions such as availability of knowledge. The adaption in itself consists of 1) the four cornerstones of resilience (Hollnagel et al., 2007) anticipating, monitoring, responding and learning; and 2) interactions between sharp-end and blunt-end.

The successful adaptions among the technicians at the field trips can be described in such a framework. Their adaption is a function of the context of the action that consist of their ability to monitor and anticipate the situation. The technicians' tacit knowledge is a key contributor to their ability to adapt to the situation, not least because the success of the actions depend on the decisions made at sharp end due to lack of communication infrastructure with the blunt end.

The tacit knowledge among the technicians and their ability to adapt to the situation are essential in both cases for maintaining safe travels in continuously changing variable conditions. Scenario 1 has several elements which made it more difficult than a normal to drop off or pick up in the field. Tacit knowledge from the technicians which is acquired through multiple seasons and hundreds of hours of driving boats around the Isfjorden area was vital to complete this task in a safe and effective way. The snow mobile trip in scenario 2 was successful for many of the same reasons that the boat trip was successful. The technicians were able to use their past experience and knowledge to anticipate the hazards and then act accordingly. Flexibility plays an important role. The technicians were able to put in much more work than is normal for this kind of trip. When many different hazards exist and combinations of hazards are not always predictable, tacit knowledge and experience are essential.

The two scenarios also show the connection between the sharp end—the practitioner, and the blunt end—the management. For both scenarios a key word is flexibility. Based on the experience in the sharp end from similar operations, the management can see the need for flexibility and use of extra time to adapt to the situation. Experience in the sharp end is building situational understanding in the blunt end.

Figure 4. Snow mobile travel to Svea.

4.2 *Experience feedback at an organizational level to improve coping mechanisms*

The available knowledge among the technicians at sharp-end during field trips could be improved by principles of experience feedback as illustrated in Figure 5. The framework by Rankin et al. (2014) is rooted in principles of resilience engineering.

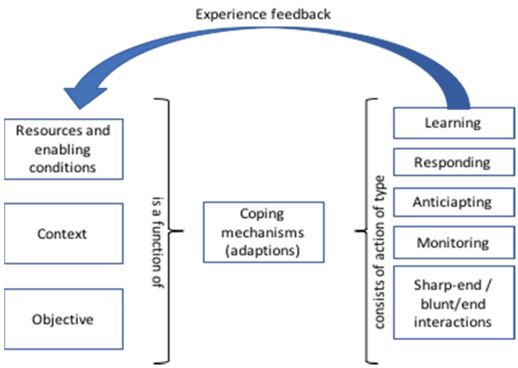

Figure 5. Framework for analysis of coping mechanisms (based on Rankin et al. 2014) and the importance of experience feedback.

Resilience engineering is centred around four main abilities: to respond, to monitor, to anticipate and to learn. The ability to learn from both failures and success is a key to improving the knowledge among sharp-end practitioners. By learning from experiences at field trips both individually and among colleagues, resources that contribute to adaptions will improve.

The technicians who participate in fieldwork with students and employees acquire new experience every day and thus maintain and develop their tacit knowledge. In addition, their tacit knowledge is generated when the they continuously close nonconformities during field trips as shown in the two cases in the prior chapter.

The individual learning is important learning for the organisation. Feedback from experiences related to everyday tasks should be shared in the organization; what works and what does not work in order.

Nonaka and Takeuchi (1995) emphasize how different transitions of tacit and explicit knowledge create shared knowledge in organizations. Socialization (from tacit to tacit knowledge) is one of the transitions that contributes to organisational learning. The technicians at UNIS start each morning with a meeting to go through the tasks/duties to be performed on that day. Ekman (2012) highlights the importance of informal conversations in making tacit knowledge visible in the organisation, and facilitating arenas that encourage small talk. The morning meetings involve a set agenda where events from the day before is discussed and the technicians inform each other of changes related to snow conditions, weather, etc. The technicians generally meet up for a cup of coffee together before this meeting. A lot of information is shared during this five-minute period that should be raised during the formal meeting. As a result, important information is not raised at the meeting with the management because it has already been shared during the small talk over coffee before the meeting. Tacit knowledge among those talking is improved, but there is potential for organizational learning in addition if this knowledge is share among more people.

Transition from tacit knowledge to explicit knowledge (externalization) will also contribute to organizational learning (Nonaka and Takeuchi, 1995). Within safety management, systems for reporting of unwanted occurrences is an important contribute to externalization of tacit knowledge, but also to combination of explicit knowledge as well as internalization (from explicit knowledge to tacit knowledge) (Kjellén and Albrechtsen, 2017).

Such learning among technicians wil happen in communities of practise (Wenger, 1998). Communities of practice is a group of humans that has a mutual engagement, common goals and activities and a common repertoire of actions and resources (Wenger, 1998). Among the primary parts of learning in communities of practice we find social participation, sharing stories, apprenticeship learning, and that learning is a complex social phenomenon dependent on context.

How can one use and systemise the informal “coffee break” to strengthen learning in the organisation? Ekman (2012) refers to the importance of horizontal meeting places for the tacit knowledge where every day experiences can be shared. It is also possible to learn from conversations about a completely normal day. It provides an opportunity to test out the prevailing knowledge and create new learning. A traditional view in the field of safety is that one learns from mistakes and incidents. However, in more recent times, it has become more common to focus on learning from successful tasks (Hollnagel, 2014), which after all is most of the tasks one performs during a working day. By learning from everyday events, it is possible to test the prevailing knowledge and, in doing so, uncover practices that are unsafe, even though no accidents have occurred. “Learning from successful operations is not only about identifying and promoting good practice, it is also about detecting the instances where no accident occurred in split of unsafe practices or unsafe systems” (Rosness et al., 2016).

4.3 *Contextual change that affect experience feedback*

UNIS experience increased student production and rapid changes in the natural environment. Ashby´s (1961) law of requite variety states that control of a system is achieved only when the variety of countermeasures matches the variety and changes of the system. This implies that the field technicians must acquire new knowledge and put this into effect to deal with the contextual changes of their field activities. Systems and practises for experience feedback would enable improved knowledge to handle new situations.

Growth is not only a matter of increasing staffing to deal with the increased activity. One must also make structural changes to ensure that the environment for learning from tacit knowledge and making this visible is as favourable as possible. If one looks at organisations that manage to exploit tacit knowledge, facilitating communication is a key factor. Structurally, one can facilitate the rapid spreading of knowledge and spend time on systematic training and review the composition of the work group to attain a mentor effect.

5 CONCLUSION

Successful field operations at the University Centre in Svalbard depend heavily on safety technicians that have the responsibility to assist in the planning and execution of every type of field work. Due to changing conditions, local variations, extreme weather conditions, lack of access to infrastructure and communication successful safety performance is created by individual's ability to adapt to situations. This paper has demonstrated that this ability to a large extent is a function of the tacit knowledge of the technicians. To improve the tacit knowledge of each technicians, systems and practices of experience feedback must be run to ensure individual and organizational learning from both failures as well as successes. This is in particular important in systems with great variability in climatic conditions and systems with organizational changes.

REFERENCES

Argyris, C., & Schon, D. A. (1996). Organiational learning II. Addison Wesley.

Ashby, W. R. (1961). An introduction to cybernetics. Chapman & Hall Ltd.

Crossan, M. M., Lane, H. W., & White, R. E. (1999). An organizational learning framework: From intuition to institution. Academy of management review, 24(3), 522–537.

Cyert, R. M., & March, J. G. (1963). A behavioral theory of the firm. Englewood Cliffs, NJ, 2.

Deming, W.E. (1993). The new economics for industry, government and education. MIT Press, Boston, MA.

Ekman, G (2012), Fra prat til resultat—om lederskap i hverdagen, Abstrakt forlag [in Norwegian].

Foguem, B. K., Coudert, T., Béler, C., & Geneste, L. (2008). Knowledge formalization in experience feedback processes: An ontology-based approach. *Computers in Industry*, 59(7), 694–710.

Hollnagel, E. 2014. Safety-I and Safety-II: The past and future of safety management. Ashgate, Aldershot, UK.

Hollnagel, E., Woods, D.D. and Leveson, N.C. (eds.). (2007). Resilience engineering: Concepts and precepts. Ashgate, Aldershot, UK.

Jacobsen, Thorsvik (2016) Hvordan organisasjoner fungerer, 4 utgave, Fagbokforlaget. [In Norwegian].

Juran, J.M. (1989). Juran on leadership for quality—An executive handbook. The Free Press, New York.

Kjellén, U. & Albrechtsen, E., (2017). Prevention of Accidents and Unwanted Occurences. CRC Press.

Nonaka, I., & Takeuchi, H. (1995). The knowledge-creating company: How Japanese companies create the dynamics of innovation. Oxford university press.

Rankin, A., Lundberg, J., Woltjer, R, Rollenhagen, C. & Hollnagel, E. (2014) Resilience in Everydat Operations: A Framework for Analyzing Adaptions in High-Risk Work. *Journal of Cognitive Eningeering and Decision-Making*. Vol. 8, No1, pp.78–97.

Rosness, R. Haavik, T. Tinmannsvik, R.K. (2016), What do you do when you build safety? Practitioners' guide to learning from successful operations. Trykkpartner AS.

Wenger, E. (1998). Communities of practice: Learning, meaning, and identity. Cambridge university press.