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WORKING MATERIAL

Preservation of knowledge: general principals, methodology and application in nuclear industry

Report prepared within the framework of the Programmes:
C.3. Nuclear Knowledge Management and
A.2. Improving Quality Assurance, Technical Infrastructure and Human Performance

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FOREWORD

There is an immediate need to preserve existing knowledge in nuclear science and technology for peaceful applications for future generations, as it represents a valuable human capital asset. The development of an exciting vision for nuclear technology is prerequisite for attracting young scientists and professionals to seek careers in nuclear science and technology.

Irrespective of current national energy policies, the need to maintain or even enhance the nuclear knowledge base and national capability will persist. In this way, the knowledge base will be available to meet requirements for evolving policy development. A number of IAEA advisory committees and technical meetings stressed the importance of preserving and further enhancing nuclear science and technology for socio-economic development. For nuclear science and technology to contribute to sustainable development requires knowledge and capacity on three levels: (a) basic nuclear science, (b) technology, (c) engineering and operation. There was unanimous consensus that IAEA has an obligation to lead activities towards preservation and enhancement of nuclear knowledge by complementing, and as appropriate supplementing, activities by governments, industry, academia and international organizations. International co-operation is of vital importance. Unless action is taken now, invaluable assets in critical nuclear knowledge and capacity will soon be lost.

The need to sustain the present level of deployment of nuclear technology (energy and non-energy alike) requires urgent action throughout the nuclear community and beyond. The Agency, in particular, is requested to use its potential in assisting Member States to ensure the preservation of viable nuclear education and training which is a necessary prerequisite for succession planning. The needs may be even more pressing in Member States that consider nuclear power essential for their national sustainable development objectives and face expanding nuclear programmes.

The IAEA is developing guidance documents on nuclear knowledge management including knowledge preservation and knowledge transfer in nuclear sector.[1] This activity would assist nuclear organizations in MS to effectively apply this guidance, and to assist them in benchmarking their practices against those of other industry organizations.

The present Working Material provides general principals for knowledge preservation in nuclear sector, which could be applied in different nuclear organization and in particular in Nuclear Power Plants.

Appreciation is expressed to all the participants who contributed to the Technical Meeting activities, listed at the end of this Working Material. Particular thanks are due to S. Koruna (Switzerland) for his assistance in the preparation of a draft manuscript on the meeting topic.

Technical officers responsible for a preparation of this working material were Yanko Yanev and Andrei Kossilov, NE/Nuclear Knowledge Management Unit.

[1] For already published documents see http://www.iaea.org/Publications/index.html

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1. Management Summary

The nuclear industry is currently facing several challenges. An internal threat to the safety and operations of nuclear power plants is the loss of those employees who hold knowledge that is either critical to operations or safety. This report discusses the possibilities to preserve knowledge in nuclear power plants.

The major threat to any knowledge-based operation is the often unclear relationship between the employees' knowledge and the organization's output. Depending on whether the organizational activities are rather product- or process-oriented the identification of the critical knowledge is organized differently: while product-oriented activities are rather task driven, the first unit of knowledge preservation analysis in such environments is the task. It is analyzed which employees contribute to the task and how important each employee's contribution to the task fulfillment is. In process-oriented environments a similar procedure is followed. Here the process is analyzed according to which employees provide process input and how critical this input is to the process output. In both situations, those employees that provide critical input to the task/process become the unit of analysis.

Employees are analyzed according to which knowledge bases they dispose of and deploy in order to reach their objectives. Knowledge is seen as the capacity for effective action and the result of a process that integrates expertise, methodological knowledge, social competence and meta-knowledge.

Knowledge can be differentiated into two types of knowledge: explicit and tacit. While explicit knowledge is not too different from information, tacit knowledge is tough to grasp and tough to handle. While people are able to ride a bicycle or to swim, they are normally not capable to explain why they are able to do this. This is a problem for an organization when it wants to preserve knowledge. Thus tacit knowledge poses the primary barrier to knowledge preservation. Dependent on the degree of tacitness two different knowledge preservation strategies can be discerned: personalization and codification.

The *personalization* strategy for knowledge preservation comprises the creation of substitutes, the establishing of mentor/novice partnerships, communities of practice and the deployment of external experts. Generally, from a 'preservation' point of view, the personalization strategy is superior to the codification strategy as it creates a second source of knowledge for the organization. This is important to all activities that are time-critical and where action cannot be waited for.

On the other hand, when action is not time-critical, codification strategies can provide valuable services. They comprise the classical activity of documentation, exit interviews, de-briefings, knowledge elicitation, and simulation. The major disadvantage of the codification strategy is related to tacit knowledge. To create a document which allows a recipient to reconstruct an expert's knowledge base is one of the most difficult endeavors in knowledge management. Knowledge is – normally – not free of context. Rather, knowledge is deeply rooted in context. To understand an activity often depends on understanding the context in which the activity took place. When documents are created, context is often neglected. In such a situation the reconstruction of knowledge at the recipient is difficult (or even impossible). Furthermore, tacit knowledge cannot be easily transferred on paper. Over time, people mask the relation between knowledge, action and output: a novice car driver switches gears thoughtfully while an experienced driver does not even pay attention to think about that procedure. He/she simply does it. The same is true for experts: do often do not have to think, they simply do (without having to think why they should do).

Accordingly, it is very difficult to elicit knowledge, i.e. making explicit again the relation between knowledge, action and output. Such a process can take months or even years and it is the question how important this knowledge is to the organization to engage itself in such an activity. In some instances, there is no way around elicitation. This is the case when organizations want to develop simulations as a means for knowledge preservation.

To conclude, the knowledge preservation activities discussed can be valued according to the criteria

- ☐ cost,
- ☐ immediacy of availability and
- ☐ completeness.

Based on those criteria the following picture emerges:

	Costs	Immediate Availability	Completeness
Substitution	👎	👍	👍👍
Tandem	👎	👍	👍
Communities of Practice	👎	?	👍
External Experts	👎	👎👍	?
Documentation	👍	👎	👎
De-Briefing	👎👍	👎	👎
Exit Interview	👎👍	👎	👎
Knowledge Elicitation	👎	👎	👎👍
Simulation	👍	👎	👎👍

One can clearly see where the strengths and the weaknesses of the various knowledge preservation strategies are. As there is not a single superior preservation strategy, the best strategy has to be chosen depending of the concrete situation. Furthermore, the strategies are complementary and not exclusive.

2. Knowledge preservation: Why it is a necessity and not a fad

In several countries the generation of the so-called baby boomers is approaching the age of retirement. When those people will retire a lot of knowledge too will walk out of the companies where those people used to work. Some examples might illustrate this point:

- ☐ When piano manufacturer Steinway decided to resume the production of a model which it had discontinued some time ago, the company discovered that it did not have any records or blue-prints at its New York facility about how to produce the piano again.

- ☐ Throughout the 90es, more than 50.000 people were laid of at Boeing. Due to an unknown and increasing number of problems with Boeing airplanes the FAA started an investigation into the causes of these problems. Its report was published in October 2000 and it stated that there were considerable systematic errors and problems at Boeing in the areas of production and engineering (Liebig, 2001). Further more, as a result of these layoffs the firm realized it had laid off the wrong employees. In the end, this misstep caused the firm to rehire 9000 of the employees it had laid off before.

- ☐ Shortly after one of its computer systems experts had left the company, a Swiss Bank faced tremendous problems. As those problems needed to be solved and no one inside the firm was able to do so, the expert demanded the company to pay around $ 250.000 for his services. The company paid (Probst and Knaese, 1998).

- ☐ In April 1996, Deutsche Bank lured away the now-infamous investment banker Frank Quattrone from US rival Morgan Stanley. Two years later, the company not only lost Mr. Quattrone to Swiss Rival Credit Suisse First Boston, it also lost most of the team (analysts, bankers and salespeople) Quattrone had built up: In all, 100 analysts, bankers and salespeople jumped to CS First Boston, following Frank Quattrone, their boss at Deutsche Bank Securities, who left the unit of Germany’s Deutsche Bank AG.

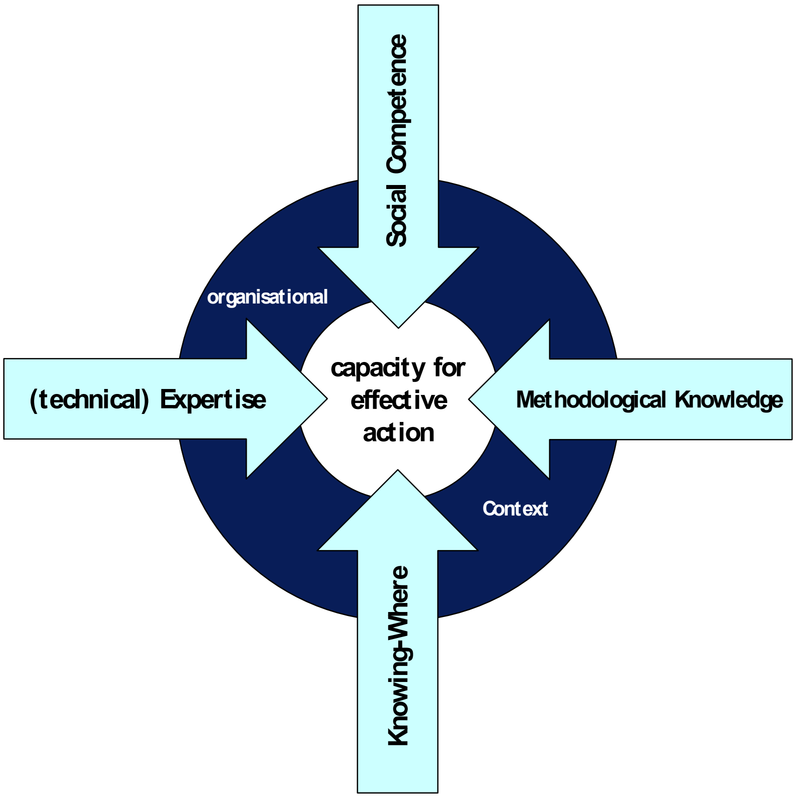
- ☐ In the months following July 1999, Dutch bank ABN AMRO suffered the loss of several key employees, threatening its US securities business: First, it lost its leader in the oil business to Credit Suisse First Boston, then its boss and the leading executives of the pharmaceutical business, and – finally – in September 1999 it lost its star research team to US competitor Morgan Stanley (Graham, 1999).

Those examples emphasize one point: It is not only important to firms to attract top talent, it is even more important to keep talented people inside of firms and to do their best to keep their knowledge inside of the firm when these people leave – either for a new job or for retirement.

The reason why the departure of employees from the firms will be accompanied by massive losses of knowledge cannot be explained without explaining some aspects of what knowledge is.

To understand the consequences of key personnel turnover the nature of knowledge has to be understood. Assumptions regarding knowledge and what knowledge is are differing widely. Here, a so-called constructivistic understanding of the knowledge concept is suggested. Thus, knowledge is seen as a personal and highly subjective construction which is strongly related to the context within which it was created (Galunic and Rodan, 1998; Nelson and Winter, 1982). We then can define knowledge as those cognitive structures a person develops over time and which allow her/him to act and to achieve successfully the results intended.

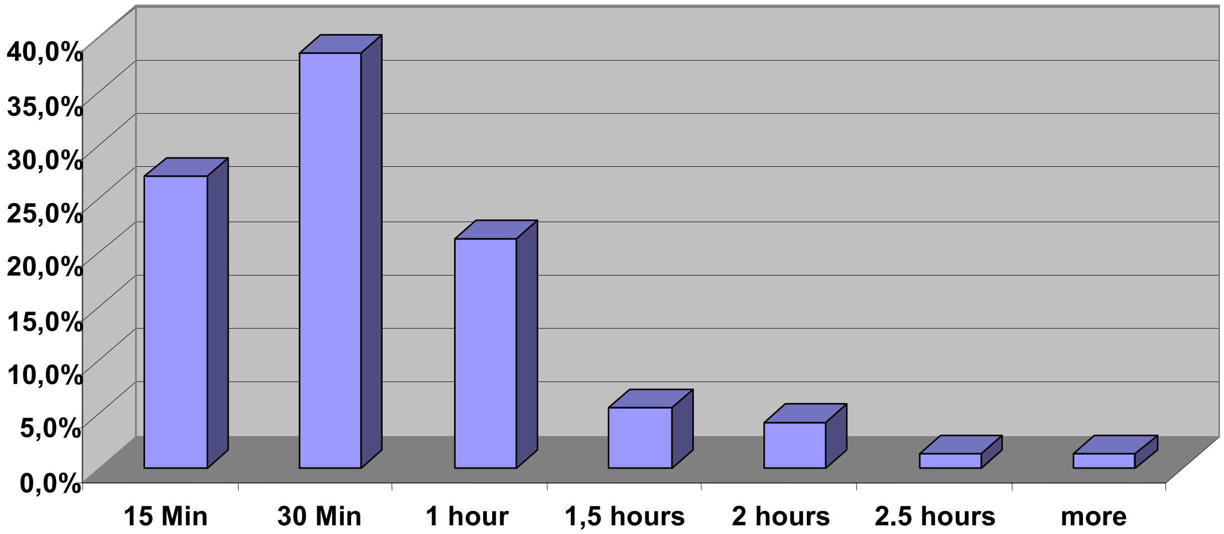
Figure A1: Capacity for effective action as the result of a fourfold integration process.



Peter Senge (1999), former professor at the Massachusetts Institute of Technology and now Chairperson of the Society for Organizational Learning defines knowledge as the *capacity for effective action*. Senge's definition of knowledge is chosen as it integrates the concept of action into the concept of knowledge. From this point of view, being knowledgeable means to be able to achieve the results a person is expected to deliver. Such a capacity for action is seen as the result of an extensive integration process (see figure A1) that consists of integrating technical expertise, methodological knowledge and social competence.

Furthermore, the capacity for effective action heavily depends on an individuals efficiency and effectiveness to search and deploy knowledge (see figure A2).

Figure A2: Importance of knowing-where: Search times for information in a German engineering firm.



Knowledge exists in two different forms: an explicit and an implicit form. When we ask a person: how do you do this?, a person will give us a few explanations why he/she is performing certain steps to achieve a certain objective. Those explanations can be written down and transferred easily to interested parties. However, a novice reading those instructions still might not end up with the same results as the expert. Just compare the results of a novice and an expert cook. To the expert, many aspects of cooking are not worth mentioning. He/she is doing them unconsciously. Further more, he/she will feel when the meat is ready or not. The difference in the output between the novice and the expert cook is called tacit knowledge. Hungary-born philosopher Michael Polanyi (1966) identified such knowledge as critical to human performance.

As such knowledge cannot easily be articulated (or rather: never be fully articulated), documents never comprise the experts' complete knowledge. That means that an employee leaving a firm always takes knowledge with him/her that will – later on – not be available any more to the firm. The impact of this loss will not become apparent immediately. It will become apparent when this knowledge is not available the next time it is needed. Then the loss of the employee/knowledge will be felt. That it is not felt before is related to the often unclear relationship between tasks, employees and the knowledge involved. As this relationship is largely unclear the whole impact of losing employees is often underestimated. Thus it is important to identify – or rather: make evident – the relationship between individuals and organizational performance. Whenever this relationship points to critical knowledge distributions (e.g. only one person or two persons can do a certain task), preservation activities should be initiated *immediately*.

Knowledge preservation is affected by both the unclear relationship of firm performance and employees' contribution as well as the tacit nature of knowledge. The primary challenge in preserving knowledge for firms is to figure out how this tacit knowledge (nevertheless) might be captured or – at least – be transferred to successors.

The good news here is that there are several ways to preserve knowledge to firms. This report is about to explain the possibilities how knowledge can be preserved for the nuclear industry (i.e. Nuclear Power Plants).

3. What business are we in: Product or process?

At first sight the headline of this chapter might confuse a reader. However, the simple question “product or process” is key to develop a viable system to preserve knowledge for any company.

The question is essential as companies differ regarding their operations. A product-oriented company deploys several processes to develop, manufacture and distribute new products. Although the manufacturing and distribution of those products are important, the key to a firm’s competitive advantage is the ability to develop new products. New product development thus is key to a firm’s competitive advantage.

Process-oriented companies (e.g. producers of electricity) largely differ from product-oriented companies. Their focus is on operating a certain facility with high efficiency. Thus, the development of new knowledge along the development of new products is not the focus. Rather, smooth and continued operation without any interruptions is key to competitive advantage.

Most firms’ activities share both aspects: product *and* process. While product development is clearly product oriented, production is clearly process oriented. Thus, both approaches have their benefits to knowledge preservation. Which methodology is deployed depends on the character of the firm’s activities.

4. Knowledge preservation in product-oriented environments

To preserve knowledge companies have to become aware of the problems that are accompanied with the loss of knowledge as a result of attrition. While such insight is important and prepares the ground for further activities, it is far from being sufficient.

To preserve knowledge effectively a firm must know which knowledge it loses when an employee leaves. And it should know whether such knowledge is important to the firm's operations or not. Thus, firms have to know which knowledge is critical and which is not.

Generally, research provides evidence that critical knowledge is defined by the customers. By deciding to buy a product from a company customers decide that certain aspects of a firm's products are superior, i.e. some product attributes differentiate this product from the competitors' ones. By knowing what differentiates a product from its competitors' ones a company also knows what is the basis of its success and thus represents a competitive advantage. The knowledge behind its competitive advantage may rest on a team or a single individual. In the latter case the company is well advised to preserve this knowledge.

However, starting to identify critical knowledge with customer input may not always be possible. This is especially true with NPPs. Many NPPs are owned and operated by monopolistic companies. That means: often, customers cannot buy electricity from a different supplier. Thus, differentiation is not really an issue and the knowledge preservation methodology has to adapt to this situation. Rather the following question should be asked: the loss of which employee would create the most damage to us? Can this person be substituted either internally or externally?

Figure C0: Differentiation potentials of products

While every firm may know its most important employees, we propose a different starting point for knowledge preservation. To identify knowledge that is critical[2] to the organization, we propose that organizations first should identify what the basis of their competitive advantage is. This input normally comes from its customers; in the case of nuclear power plants his input may not be available as mentioned before. However, as the product delivered to the customers cannot be differentiated (electricity might be called "yellow" or "eco" in Germany; nevertheless it still remains electricity).

Nevertheless, differentiation is possible. Yet, it is limited to the domain of costs, i.e. producing electricity at lower costs than the competitors. If an organization is able to produce electricity at lower costs than its competitors, it has to find out where from this cost advantage is coming from. Here, however, we are not interested in other aspects than knowledge-based advantages. When those knowledge-based advantages are identified, the activities that lead to such advantages have to be identified next. The unit of analysis of activities are the tasks performed by the organization or its departments.

A task can be defined as part of an organization's resource transformation process: raw resources (e.g. work, electricity) are transformed into a more valuable output. To achieve the output, many single activities are necessary. Such activities shall further on be called *task*. Major tasks may be divided into sub-tasks.

To obtain the information which of the organization's activities are critical, the tasks should be ranked according to their impact on the organization. To do so, a ranking scheme as given with figure B1 can be deployed.

Figure C1: Task ranking scheme.

☐ 5 points	**When the task is not done the damage to the organization is high**
☐ 3 points	**When the task is not done the damage to the organization is middle**
☐ 1 points	**When the task is not done the damage to the organization is close to zero**

Of course, to prepare a list of all a department's activities and the ranking process itself are time consuming. Yet this initial effort will pay off because it allows to focus the knowledge preservation activities on those tasks where critical knowledge resides. As a result of identifying tasks and their importance to the firm, a task / importance matrix an be created (see figure C2).

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[2] We propose to label such knowledge as critical that contributes to a firm's competitive advantage or is indispensable to guarantee certain operations (e.g. incident handling in nuclear power plants).

Figure C2: Task / importance matrix.

Importance of the task / Tasks	1		II1		V		
Task 01					X		The task is critical to the firm!
Task 02			X				Task is important, although not critical
Task 03					X		The task is critical to the firm!
Task 04	X						The task is neither important nor critical.
Task 05	X						The task is neither important nor critical.

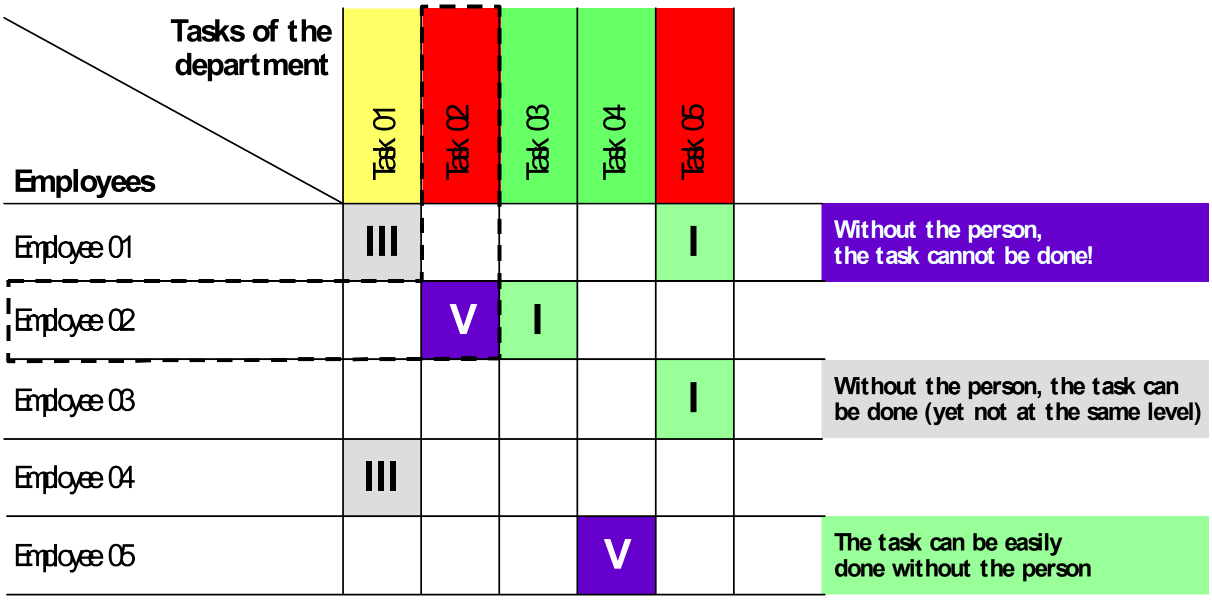
A matrix as introduced with figure C2 provides a quick impression where knowledge preservation activities should start. Certainly, the firm will have to decide (as in the case of figure C2) whether it should start with task 01 or task 03. Yet, and more important, the firm knows *where* to start! Certainly, it is beneficial to identify which tasks are important to the company and that knowledge preservation should start there. However, tasks are not executed by themselves or computers but by people. The performance of a task or even the execution may completely depend on a single individual. Thus, in the next step, the employee's impact on task performance has to be analyzed/identified. 5 points indicate that an individual is critical to a task while 1 point means that also without a specific person a task can be executed without any loss of performance.

Figure C3: Employee's importance to a task.

☐ **5 points**	**Without the person the task cannot be done at all.**
☐ **3 points**	**Without the person the task can be done. Yet, task performance is clearly below expectations.**
☐ **1 points**	**Also without the person the task can be done. Task performance and expectations match each other.**

Now, of course, both ranking schemes can be merged. The result can be seen in figure C4: it shows not only those tasks that are critical to a firm's performance but also those where the process's performance critically depends on one's or several individual's knowledge. In this example (see figure C4), tasks 02 and 04 depend a single individual's contribution. Yet, as can also be seen in figure C4, only task 02 is really critical. Performance of task 04 is affected by employee 05 but the task itself is not critical.

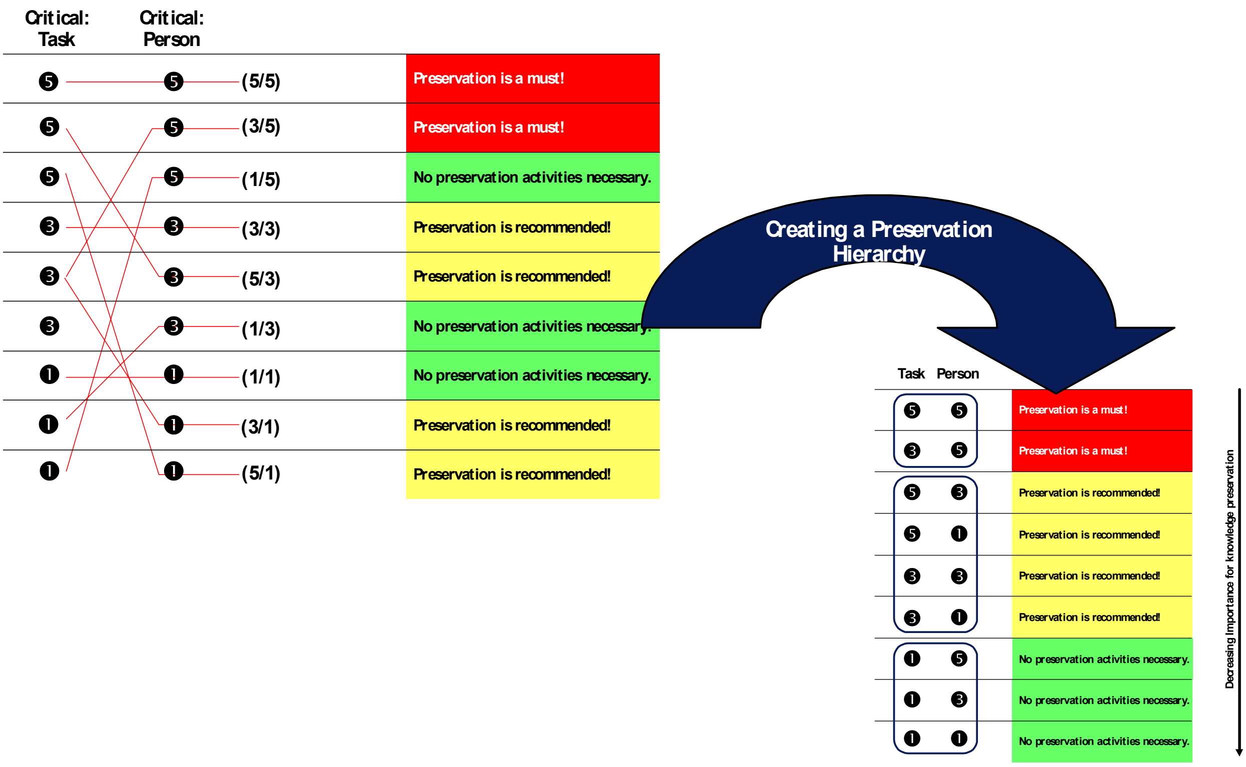
Figure C4: Employee/Task Matrix.



With the result of the Employee/Task Matrix any organization can set the direction for its knowledge preservation activities. It will not waste precious resources on activities that are not critical. Generally, as shown in figure C5, according to the combination of the values for task and person, the hierarchy for any preservation activity can be derived (see figure C5).

The development of such hierarchy is an important step for the preservation of knowledge. It is not important in itself but rather it is important for stabilizing the thrust of the preservation activities. Preserving critical knowledge demands corporate resources. Those resources are also demanded by other activities. Yet, when preservation activities demonstrate that they fulfil an important function to the functioning of the organization the activities cannot be easily challenged by those that prefer a different allocation of resources.

Figure C5: Task – Person – Necessity of Preservation Activities.



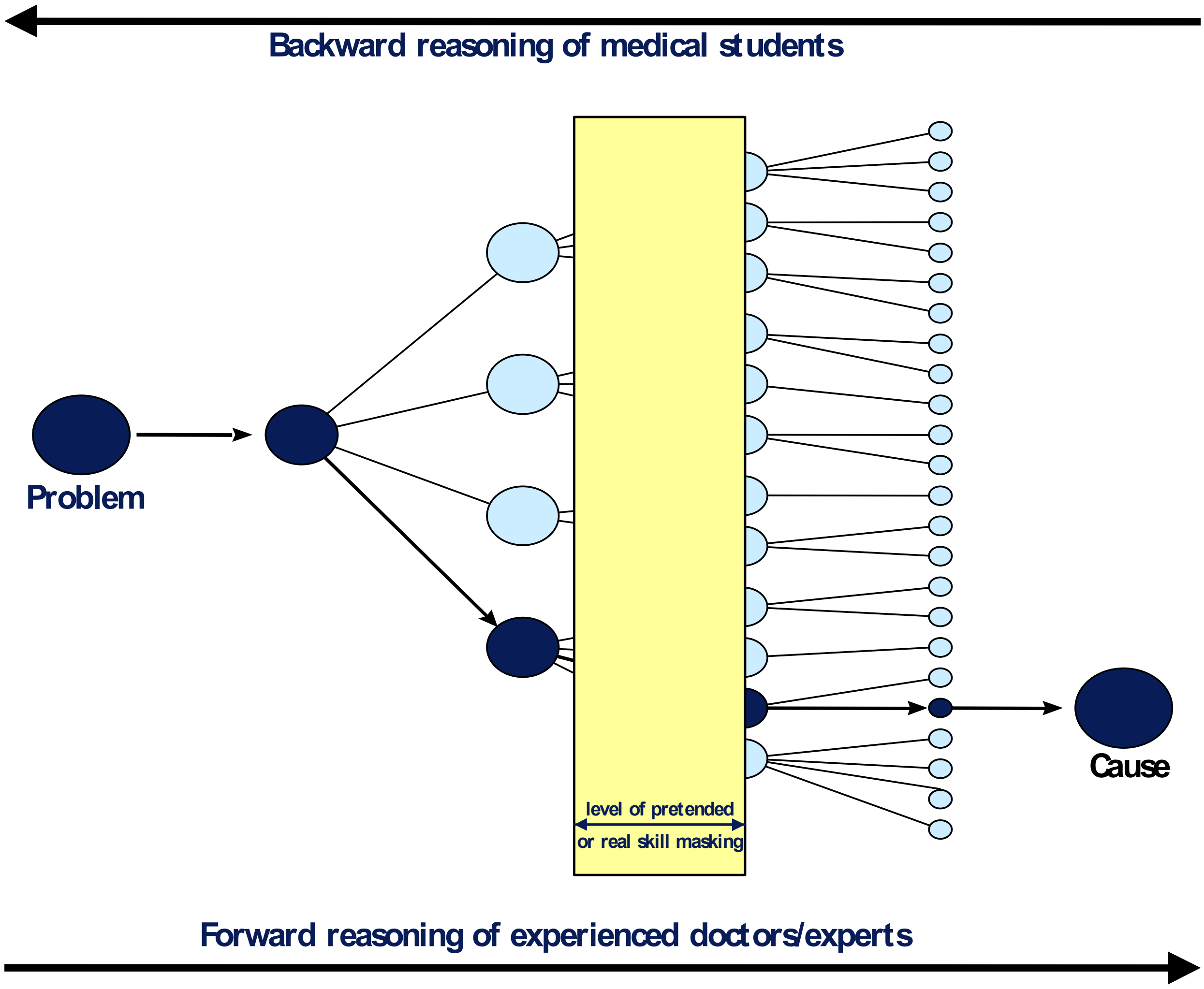
While at this point it has become clear when preservation activities should be initiated or not, it is still unclear how such preservation should occur.

Going from the ‘where’ to the ‘how’. The answer to the question how knowledge can be preserved is not easy. To ease the answer it is proposed to have a closer look at knowledge. While it has been said that knowledge is the result of a fourfold integration process (see figure A1), some knowledge is also heavily context dependent while other is not. Also, some knowledge can easily be articulated while other not. Knowledge that can be articulated exists in two different forms: articulated and non-articulated.

From a preservation point of view, tacit knowledge and non-articulated knowledge pose the greatest challenges. Tacit knowledge in itself is difficult to preserve for ‘technical reasons’ as – in the worst case – an individual may not even know what he/she knows. He/she may do things in an excellent way without being able to provide explanations for such behavior. Such inability may stem from a continuous process of unconsciously forgetting why certain things have to be done in a certain way or what is the reasons why things happen in a certain way. The most obvious prove for such masking can be found in medicine.

Expert doctors can quickly diagnose a patient's disease. Expertise research calls such an expert doctor's ability the result of *forward reasoning*. Such expertise is critical in situations when fast diagnosis is key. When medical students' behavior in diagnosing behavior is compared, a significant difference is revealed: Starting from an obvious problem, they do not directly relate the problem to a certain cause (as the experts do) but rather they go – one after another – through all possible causes and test whether this cause relates to the problem or not (backward reasoning). Figure C6 illustrates this behavior.

Figure C6: The difference between forward and backward reasoning.

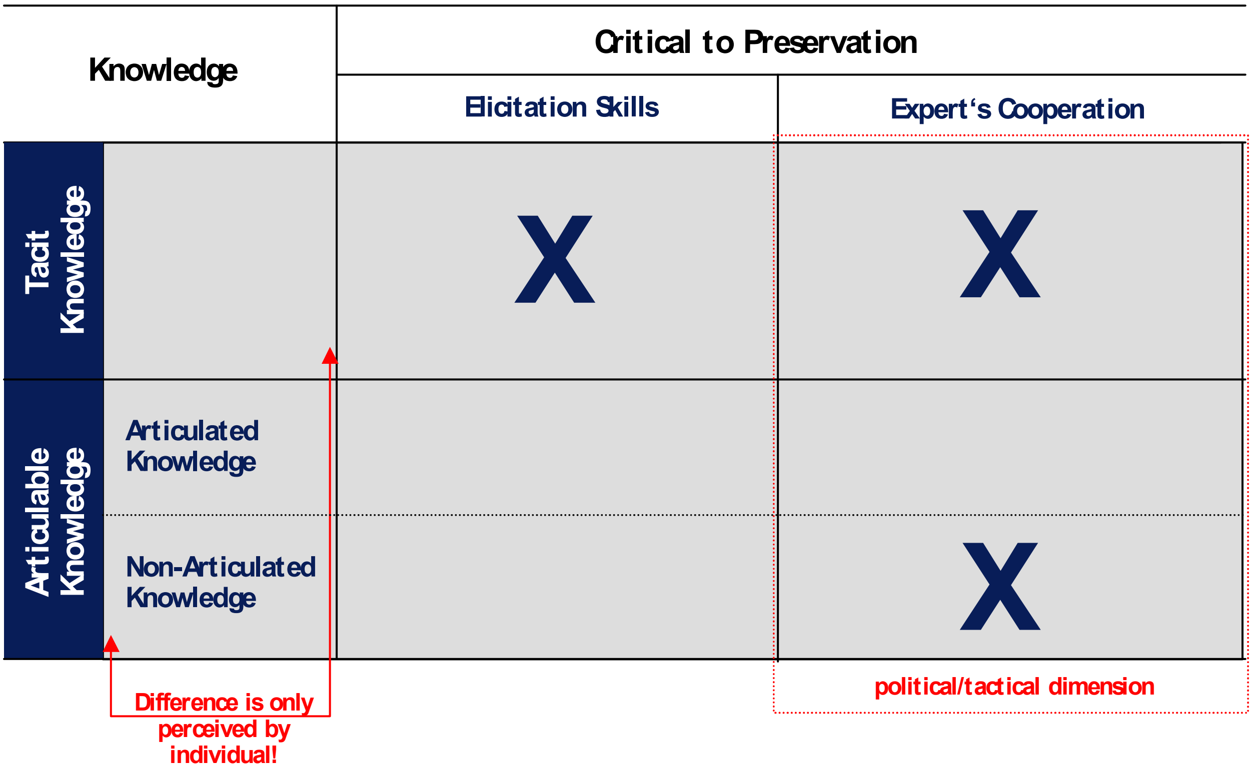


The difference in performance between the expert and the novice is the time needed for diagnosis and the accuracy of the diagnosis. While the novice lacks the knowledge of the tree structure (speaking in terms of figure C6) the expert knows the tree and its structure and knots and – based on the symptoms perceived – can thus derive the diagnosis instantly. Over time, the expert may start to forget the 'tree structure' between problem and causes yet still derive the right diagnosis. However, in case of wrong diagnosis it will be very difficult for the expert to derive why his diagnosis was wrong.

An expert who is still aware very much of the tree structure may help a team of knowledge engineers to develop a model for automated medical diagnosis – as long as he is willing to do so. For a doctor who has masked out large parts of the tree, he/she may not be able to support knowledge engineers in the same way even if he/she would be willing to do so.

The willingness to support an organization's knowledge preservation activities becomes a key issue when knowledge should be preserved that can be articulated although it has not yet been articulated. While – from an external perspective – it is not possible to verify whether an expert is not willing to disclose the 'tree structure' or cannot disclose the tree structure because of masking, in the case of articulating knowledge that can be made explicit (i.e. knowing how to fix a certain engine problem) it only depends on the individual's willingness to cooperate. Thus, knowledge preservation also has a tactical/political dimension whose influence on the process has to be taken into account.

Figure C7: Enablers for knowledge preservation.



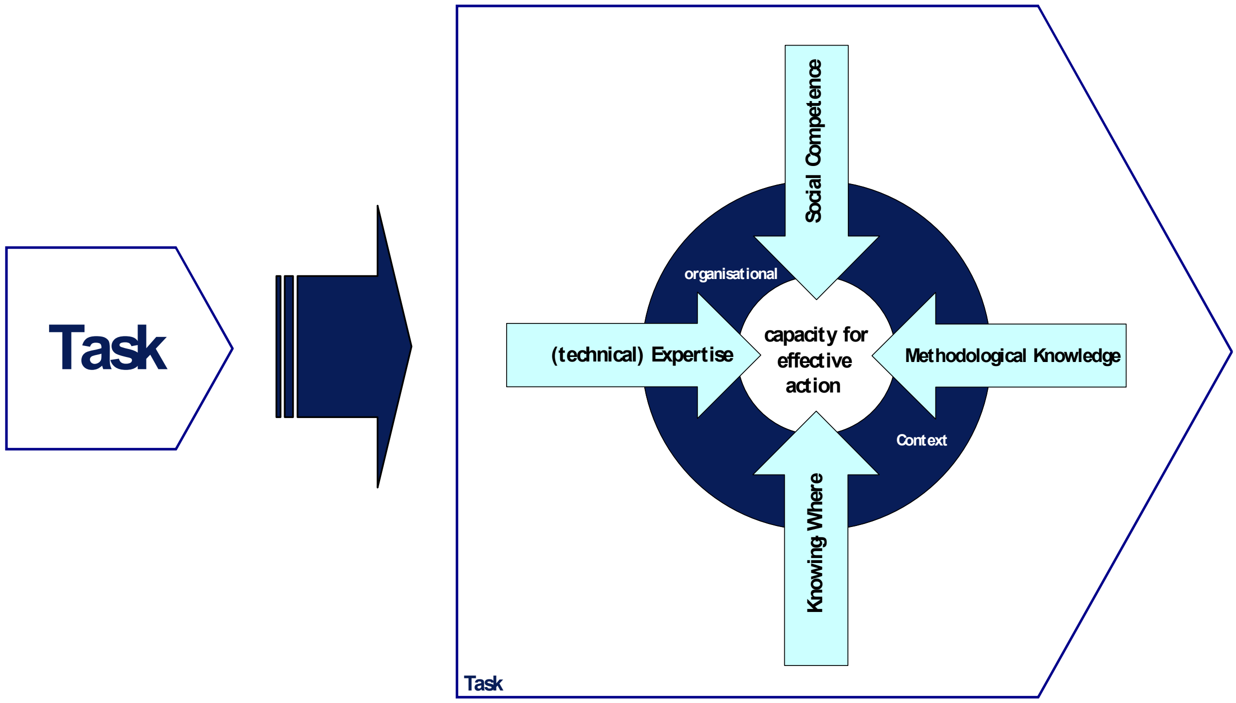
People will not support knowledge preservation activities when they expect that their contribution might – now or later on – backfire. When they ever experienced that older people were fired after they had transferred their knowledge to younger employees (and those could stay with the company), they will withhold their knowledge. They will not cooperate and they will behave as if the knowledge was tacit and they had masked the tree structure.

At this point it becomes clear that only a cooperative organizational climate will enable successful knowledge preservation. When people are afraid of losing their jobs when they share their skills any knowledge preservation will only bring disappointing results.

When an organization has ensured that its employees are willing to share what they know if they know, the next logical steps is to think how knowledge can be preserved. Here it is proposed that knowledge preservation is enabled when an individuals knowledge profile and his/her contribution to a tasks performance is elaborated.

Thus, developing the individual's knowledge profile is the next step in the knowledge preservation process. In order to achieve this objective the task will be decomposed into those elements that constitute an individuals ability for effective action as was described in figure a1 (see figure C8).

Figure C8: Task / Knowledge Decomposition.



As a result of this decomposition we can clearly see which knowledge bases are activated to achieve the necessary task performance. For illustration purposes, figure C9 covers only one part of a person's ability for effective action (expertise) while the other elements are omitted. An individual's expertise may consist of his/her ability in various disciplines, e.g. physics, chemistry, mechanical engineering or electrical engineering.

It was already the first generation knowledge management authors who emphasized the importance of knowledge maps. As a result, several papers on knowledge mapping appeared. Most of those knowledge maps – e.g. see Probst, Raub and Romhardt (1999, p. 110ff) – remain rather superficial. They related organizational tasks (e.g. M&A or technology transfer) to employees without indicating how critical the task to organizational performance is nor emphasizing how important a single individual's contribution to the task's performance is. Such first generation knowledge maps are just one step into the right direction. To preserve knowledge effectively, knowledge maps have to answer the critics mentioned above.

What is also often forgotten when knowledge maps are developed is the dynamics of the organization. Organizations are living organisms. They develop themselves further and further and they are (hopefully) far from being static. They adapt to changing environments, and they change the environment by initiating internal changes. Yet, knowledge maps are inherently static and not dynamic. To prevent knowledge maps being outdated within short time they have to be permanently updated. A knowledge map that doesn't get updated regularly is not of big use.

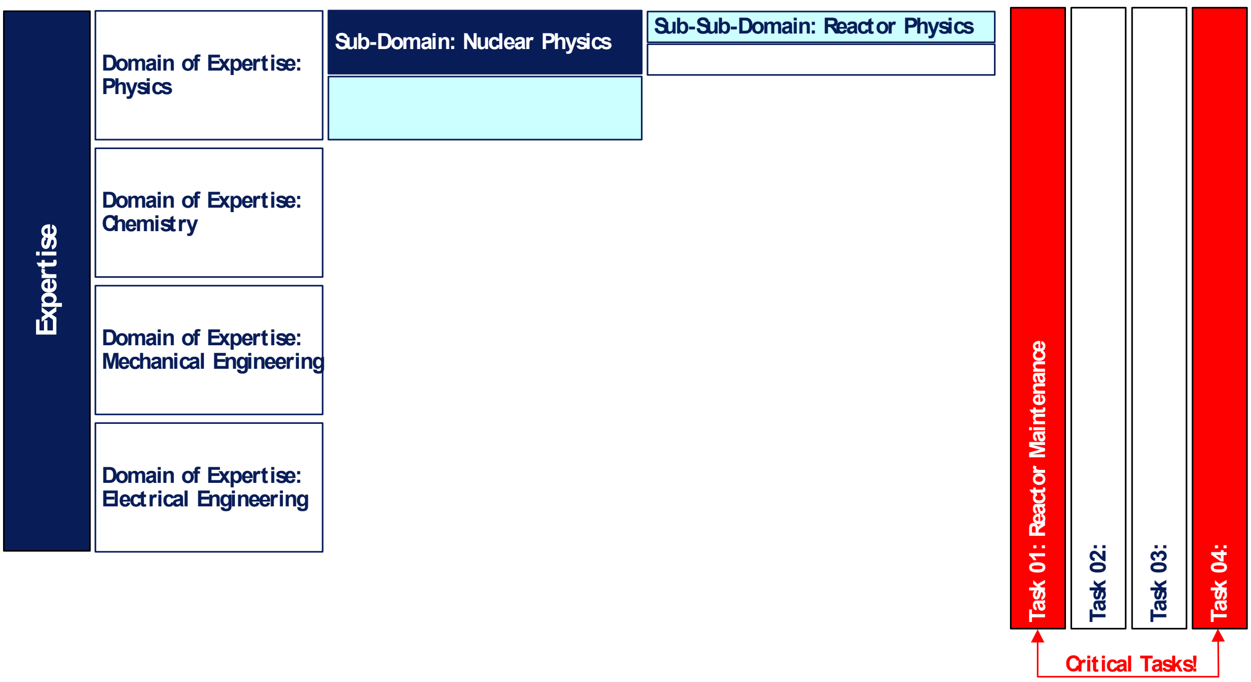
Henceforth we will try to develop second generation knowledge maps. First of all, compared to older generation knowledge maps, the domain of expertise – e.g. physics

– has to be detailed. Yet not only the domains have to be detailed, all the important domains of knowledge that contribute to a person's capability for effective action have to be identified. To do so, as illustrated in figure C9, on the left side the four knowledge bases are represented (in figure C9, though, it is for illustrative purposes only (technical/scientific) expertise).

While it is nice to know that one of our employees is skillful in physics, such information is far from useful in the context of a NPP. Here, employees knowledgeable in physics are (or should be) *the norm*. Thus, the management of a NPP that is interested in knowledge preservation rather will ask: what kind of knowledge within the domain of physics is in our employees' heads? Theoretical physics is an interesting field, but it is not of high importance to operate a NPP efficiently and safely. Thus we would like to know which sub-domains of the physics discipline are important to fulfill a NPP's objectives.

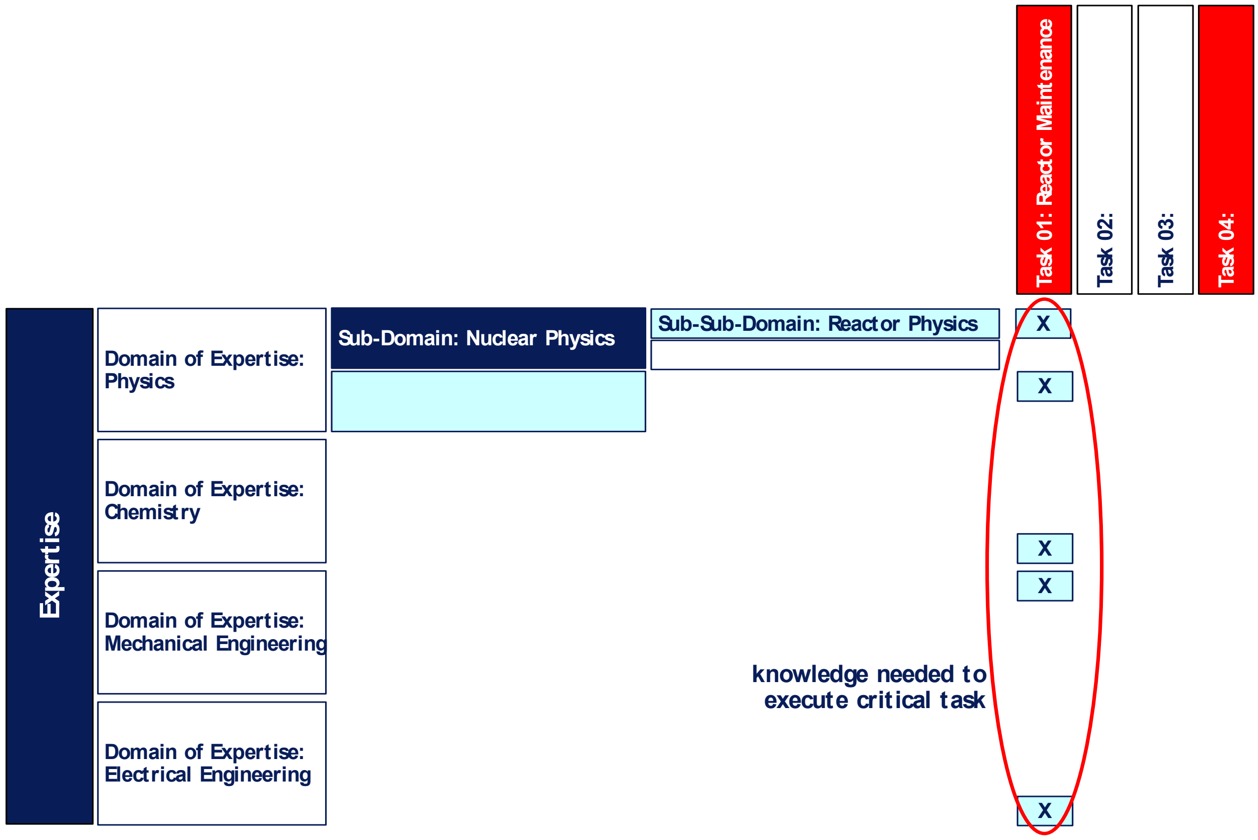
A detailed knowledge map of a NPP will not easily fit on sheet of A4 paper. Rather, it will be several sheets of A4 paper long. Although the length of such a document reduces clarity, there is no alternative to it. To reduce the length, a departmental-wise knowledge mapping effort will help. Departments are formed to reduce complexity by specializing on certain aspects. Thus, certain sub-domains of expertise or other knowledge bases may be dominant while sub-domains of other knowledge bases may even not show up in the knowledge profile of a department. For clarity reasons the white spaces in the knowledge map can be masked.

Figure C9: Knowledge Matrix.



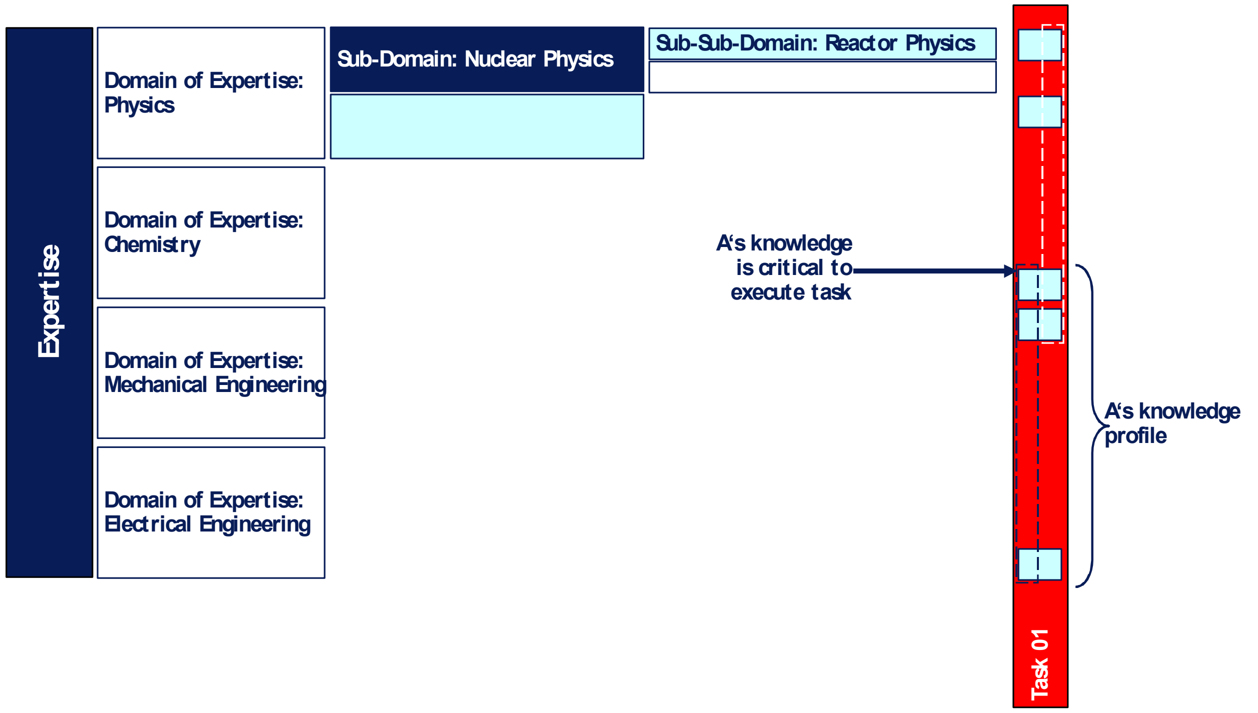
It depends upon the needs of the organization whether an organization may want to go one level further in detailing of the knowledge domains. In figure C9, a sub-sub-sub-level of the domain is not shown. What is more important, however, is to identify which knowledge bases are activated by an employee to exercise a certain task. This is illustrated in figure C10, again – for illustration purposes – in domain of expertise only.

Figure C10: Developing a task-oriented knowledge profile.



After the various knowledge bases that are necessary to execute a certain task are identified (e.g. task 01), we can develop the knowledge profile of the organization's employees. As not all employees involved in a certain task have the same duties and responsibilities, it can be expected that their knowledge bases are rather heterogeneous than homogeneous, i.e. they may differ considerably (see figure C11).

Figure C11: Task-oriented knowledge profile inside of the knowledge matrix.

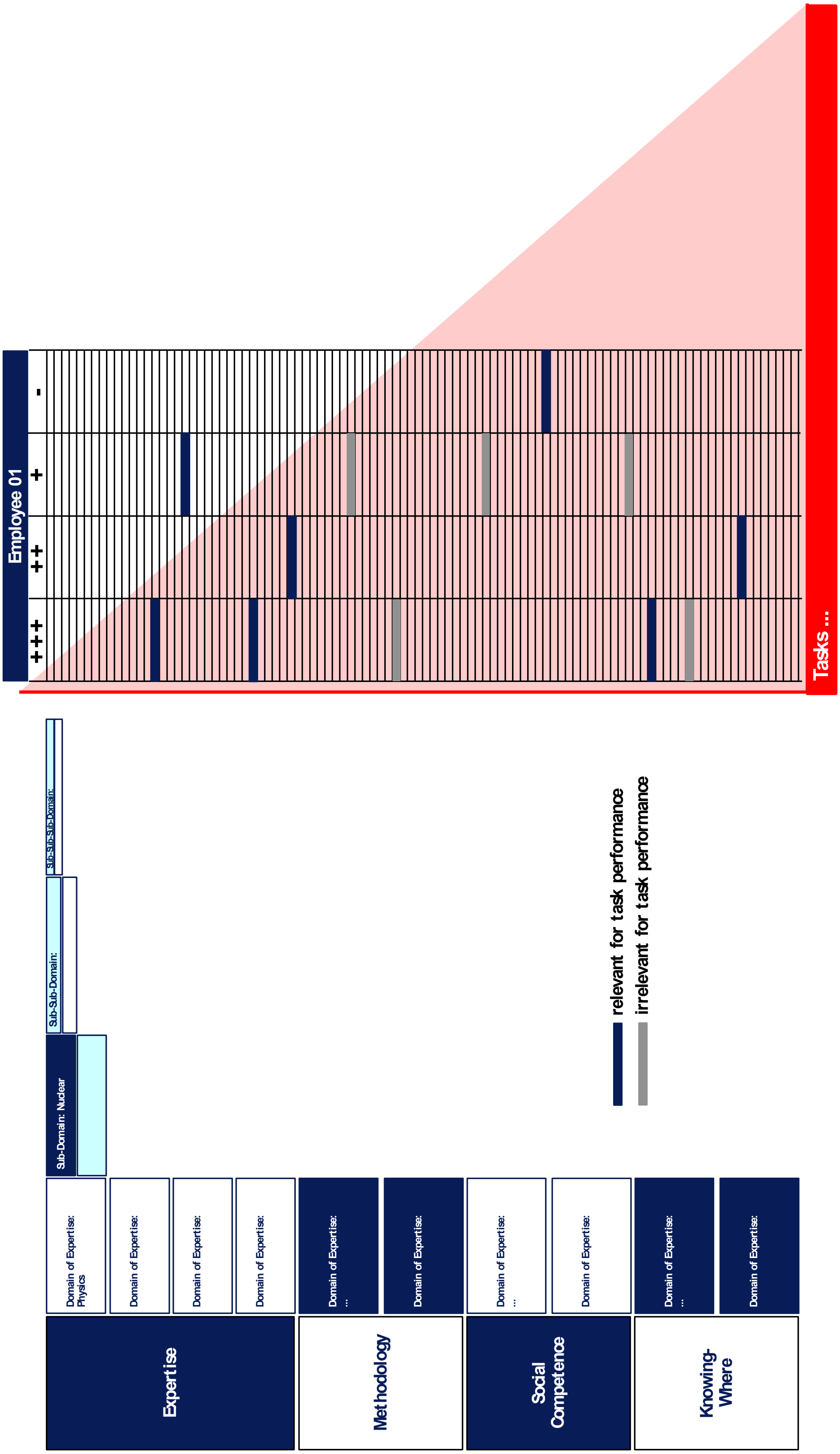


In the next step, the employee's knowledge profile is elaborated in detail. That means that the various knowledge bases that contribute to this employee's performance have to be identified and evaluated (see figure C12). This step involves close cooperation and collaboration between the supervisor and the employee. Often enough, an individual may not even know which knowledge bases have to be activated to achieve results. Here, the supervisor can provide valuable inputs. Furthermore, processes of knowledge elicitation as they were developed during the "euphoria stage" of research on artificial intelligence can help. In such a process intensive of questioning the "elicitor" tries to relate activities to knowledge bases.

The knowledge profile provides a quick and holistic view on the employee's knowledge. And it displays what knowledge is critical to achieve a certain output. Furthermore, one can quickly see where to knowledge preservation should be directed to and where (so-called irrelevant knowledge) such activities are not necessary/of high importance. As can be expected, some knowledge that employees dispose of may help them in some of their activities – yet, this knowledge may not be critical to achieve a certain task output level.

A triple plus sign indicates those knowledge bases that are to preserve first. A knowledge base may be of tacit or rather explicit character.

Figure C12: Employee knowledge profile.

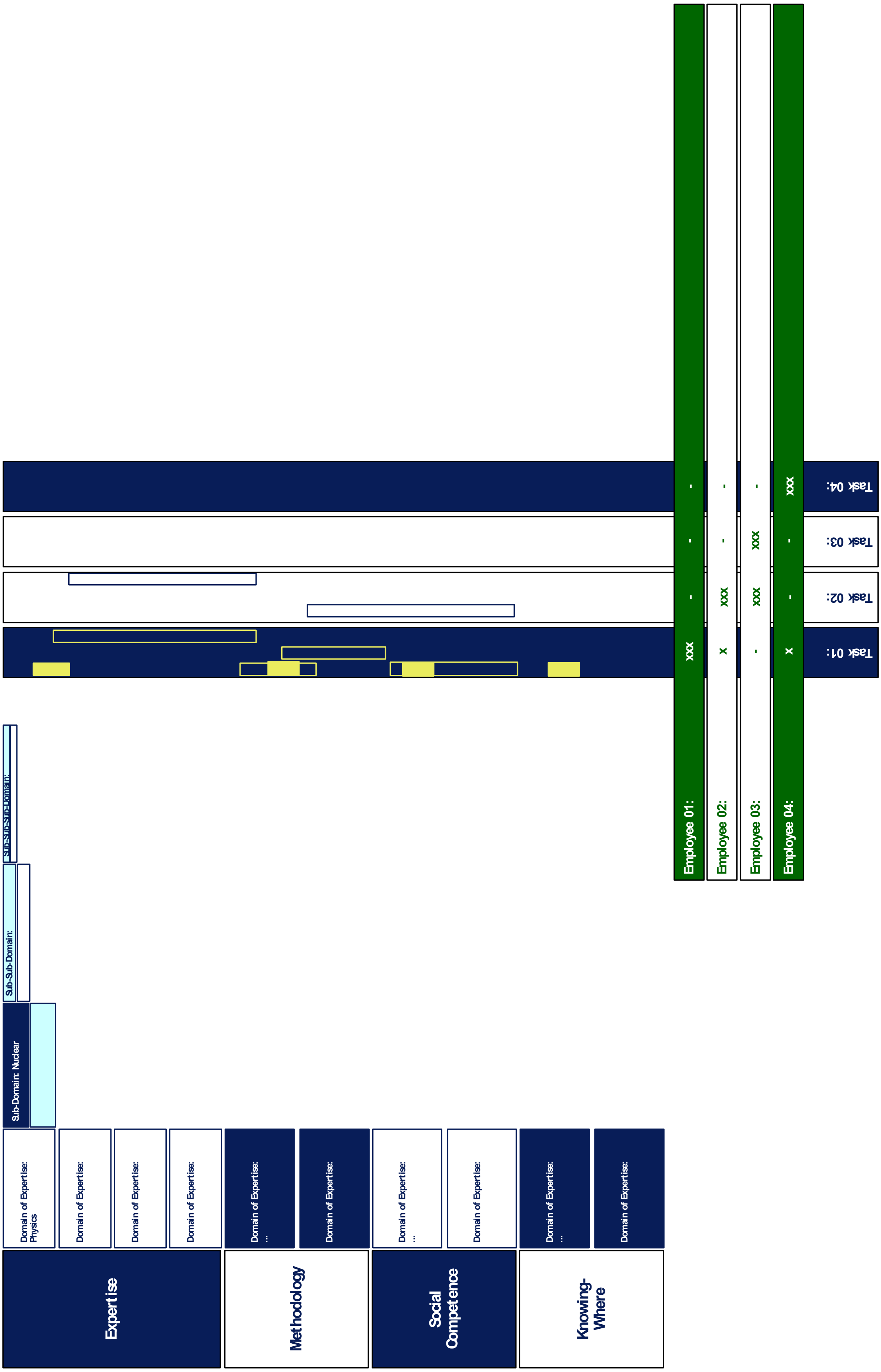


At the end of the procedure one can now merge the various process steps into one summarizing view (see figure C13). This summarizing view clearly indicates not only which knowledge is necessary to perform a certain task, it also informs which people (employees) are involved and what their contribution is and whether this contribution is critical. A triple xxx indicates that this person is critical to a task's outcome and thus this person's knowledge should be preserved. Which knowledge has to be preserved is marked by the rectangle filled with yellow color.

It is important to start any knowledge preservation activity immediately when such a critical relationship between task and employee is identified. Knowledge is not only lost when employees retire. Retirement is one of the easier-to-handle situation in knowledge preservation. Other causes of attrition – internal relocations, illness or even death – can threaten a firm's knowledge base considerably. While retirements can be planned, thos other cases of attrition come without an advance warning.

Thus: While the Tennessee Valley Authority process to knowledge preservation is mainly triggered by the time of retirement, the process illustrated here is triggered by the interdependence between necessary task output and the scarcity of the human resources to generate such output. While the TVA approach is not wrong, it does not address the fact that knowledge may be lost in other cases than retirement. To prevent such unforeseen losses of knowledge a different trigger to knowledge preservation has to be considered. Here, it is the relationship between critical tasks and employees.

Figure C11: The knowledge / task / employee matrix.



5. Knowledge preservation in process-oriented environments

Nuclear power plants definitely can be attributed to the process-oriented type of companies. They do not develop new products, although they might develop new processes to improve the efficiency of operations or reduce the risk of interruptions. Nevertheless, the focus is on process knowledge. The process orientation of nuclear power plants is highly important to the knowledge preservation activities. All analysis and activities start with the identification of the relevant processes within a nuclear power plant. The following processes can be discerned:

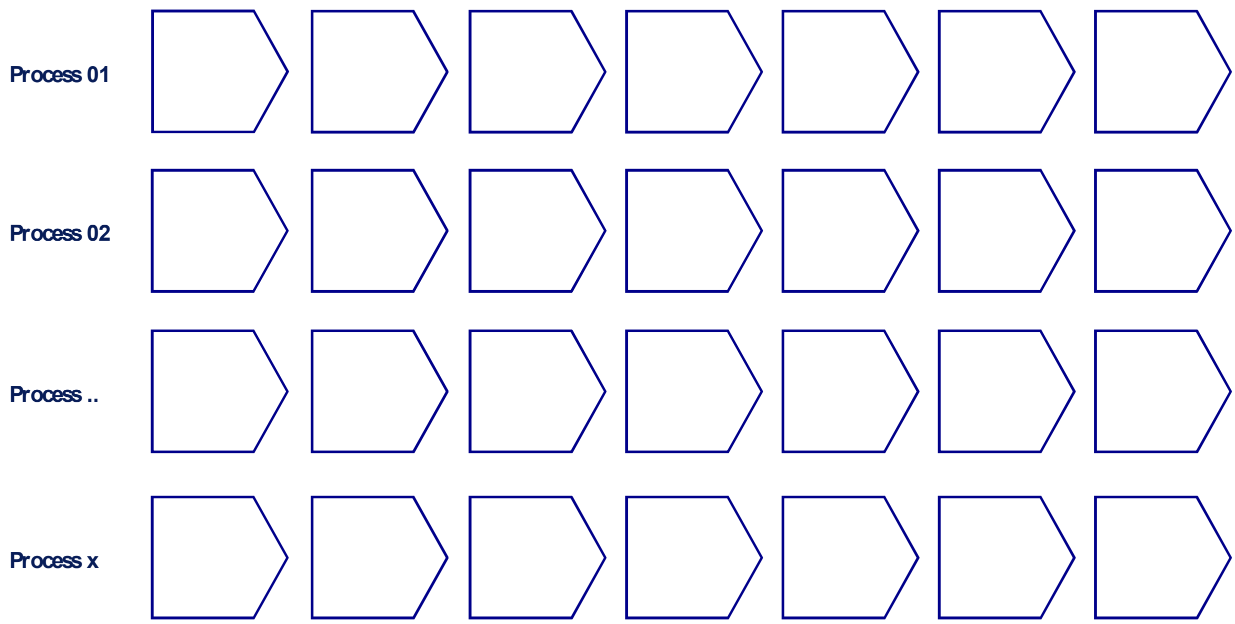
- ☐ Processes for smooth operation
- ☐ Monitoring
- ☐ Ramp-Up
- ☐ etc.

- ☐ Processes for Maintenance
- ☐ Annual replacement of nuclear fuels
- ☐ etc.

- ☐ Processes for handling interruptions (especially incidents)
- ☐ Breaking of parts
- ☐ etc.

Those processes should be well identified within modern NPPs (see Miazza, 2002) as they affect the power plants efficiency considerably. Further more, a great deal of publications has arrived in the early 90s on the subject of processes and process organizations. If the core processes have not already been identified, the first step in preserving critical knowledge is to identify those processes that are critical to operations and those to safety (see Figure D1):

Figure D1: Process landscape inside of a nuclear power plant.



Based on those processes a knowledge preservation manager can proceed to identify which steps within a process are critical to achieve a process' objectives. To identify the critical process steps they are evaluated by the process owner. To do so, he/she can deploy a ranking scheme as introduced with figure D2.

Figure D2: Process ranking scheme.

☐ **5 points**	**Process output is critical to the organization's performance**
☐ **3 points**	**Process output is important (yet not critical to the organization.**
☐ **1 points**	**The process does not play an output-critical role for the firm.**

As a result of the ranking – and completely similar to the ranking scheme introduced with the product and/or services oriented activities within an organization – those processes will be identified where knowledge preservation activities are a *must*. It is the processes that contribute the most to the organization's output that have to be targeted first in knowledge preservation activities (see figure D3).

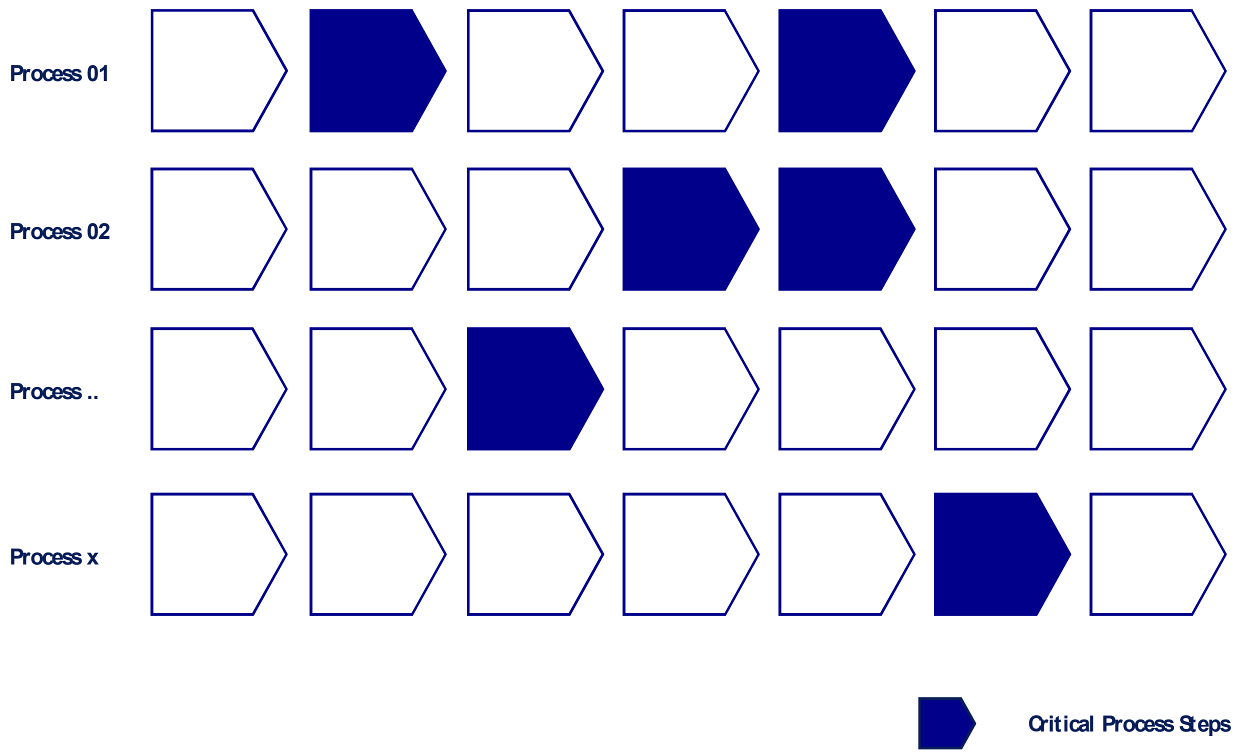
Figure D3: Identifying the organization's critical processes.

Importance of the process / Processes	1		II1		V		
Process 01					X		The process is critical to the firm!
Process 02			X				The process is important, yet not critical
Process 03					X		The process is critical to the firm!
Process 04	X						The process is neither important nor critical.
Process 05	X						The process is neither important nor critical.

Process-based organizations have become a main research topic in the early 90s of the last decade. Processes were given high importance as they were seen as a major instrument to achieve high customer satisfaction and internal efficiency. While many so-called business process re-*engineering* projects failed because they underestimated the human factor, processes have become a major factor in organizational design.

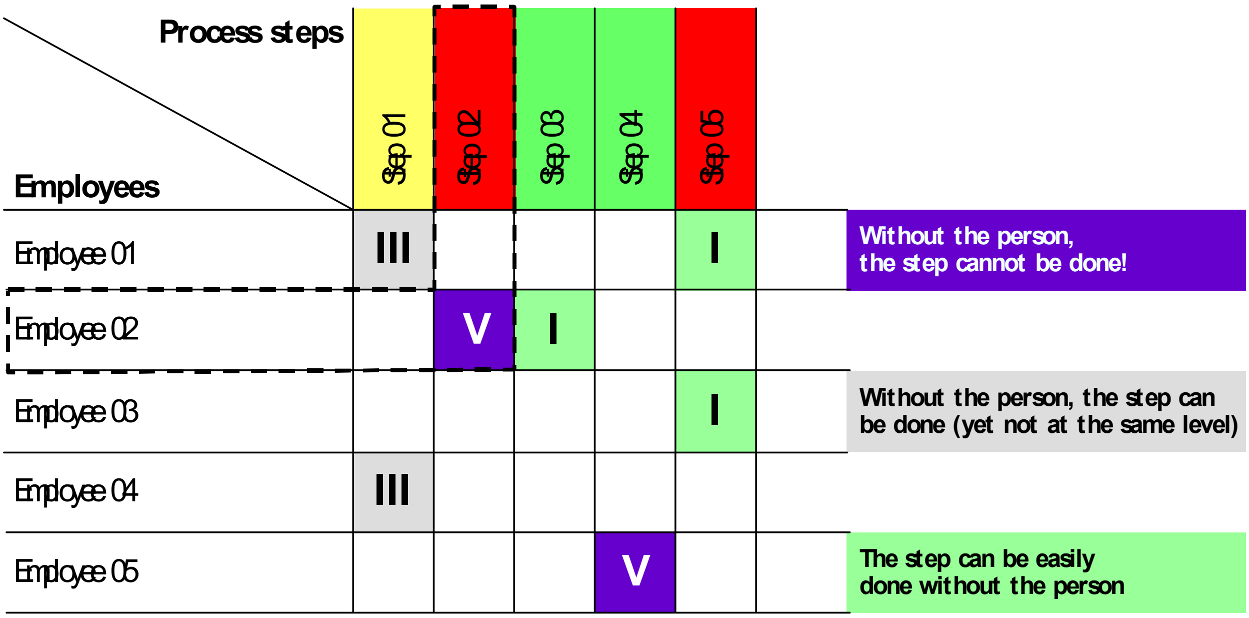
Earlier research on process management and process design clearly has shown that processes are constituted of several sub-processes. Those sub-processes represent the logical objects of a workflow. Each step contributes to the process's performance. Yet, not all process steps display the same importance regarding the process output and knowledge preservation does not reach the same importance in all process steps. The ranking scheme introduced with figure C3 for tasks can be deployed to the various process steps to identify those process steps that are critical to the overall process outcome (→ see figure D4).

Figure D4: Identification of critical steps within NPP processes.



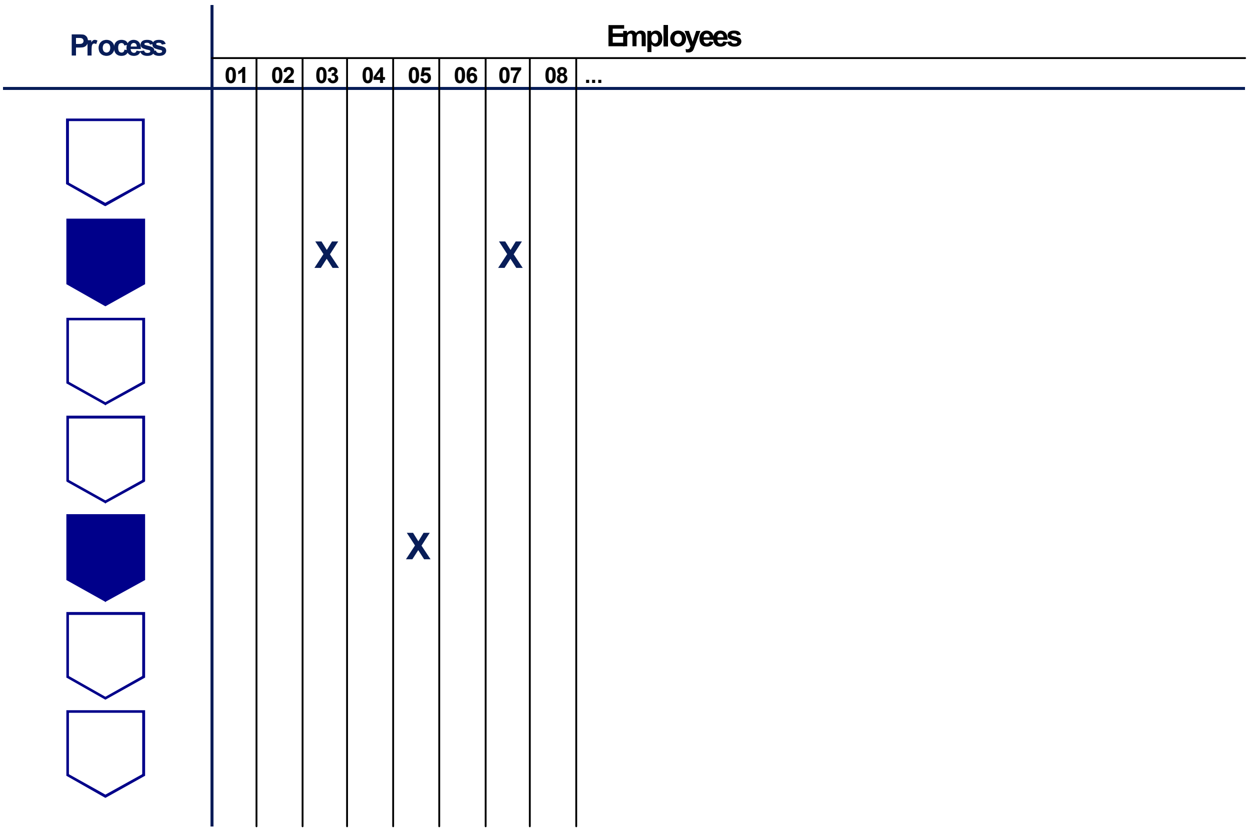
Next, those steps that were identified as critical are getting analyzed in more detail. First, the employees involved in reaching the process step's objectives are identified. Their contribution to the output is evaluated and classified. To classify their inputs it is advised to deploy the same ranking scheme that was introduced with figure C3 (see page 8). Five points will be assigned to any employee whose contribution to a process is seen as indispensable. Three points will be given to employees with considerable process input and one point to those employees that are easily substitutable (i.e. a successor's performance would not vary significantly; for details see figure D5).

Figure D5: Process step / employee contribution matrix.



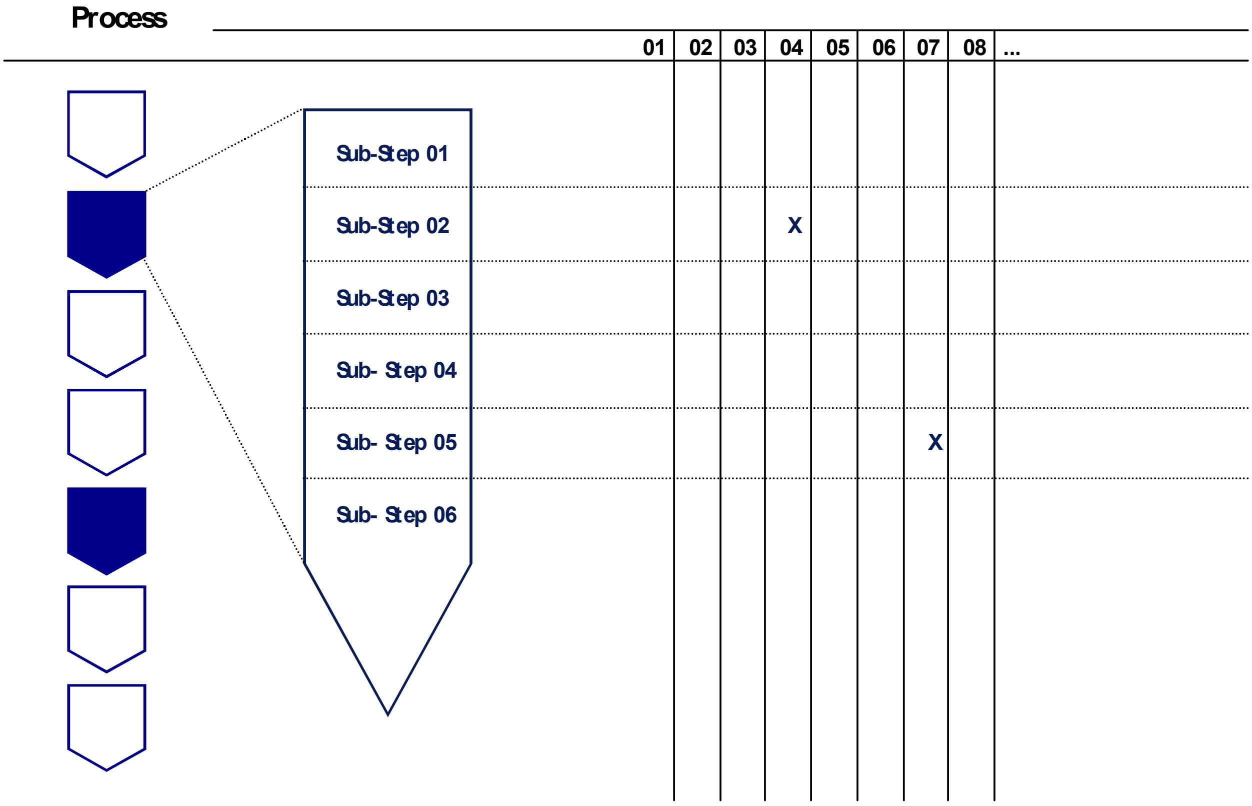
For a better understanding, only those people are indicated (see figure D6) whose process input is critical for the process input.

Figure D6: Process / employee contribution mapping.



As a result of this step a first indication is given which employees within a process may hold critical knowledge. However, as the process (see left side of figure D6) is still undifferentiated, the process step has to be examined in more detail. The process is differentiated into the various steps that are necessary to produce the process step output. Depending on the process' complexity more or less sub-steps are necessary to be performed to reach the expected output. As indicated in figure D7, it becomes evident that employees Nr. 03 and 07 are not substitutes but rather complement each other's work.

Figure D7: Process step level mapping of employee contribution to process output.



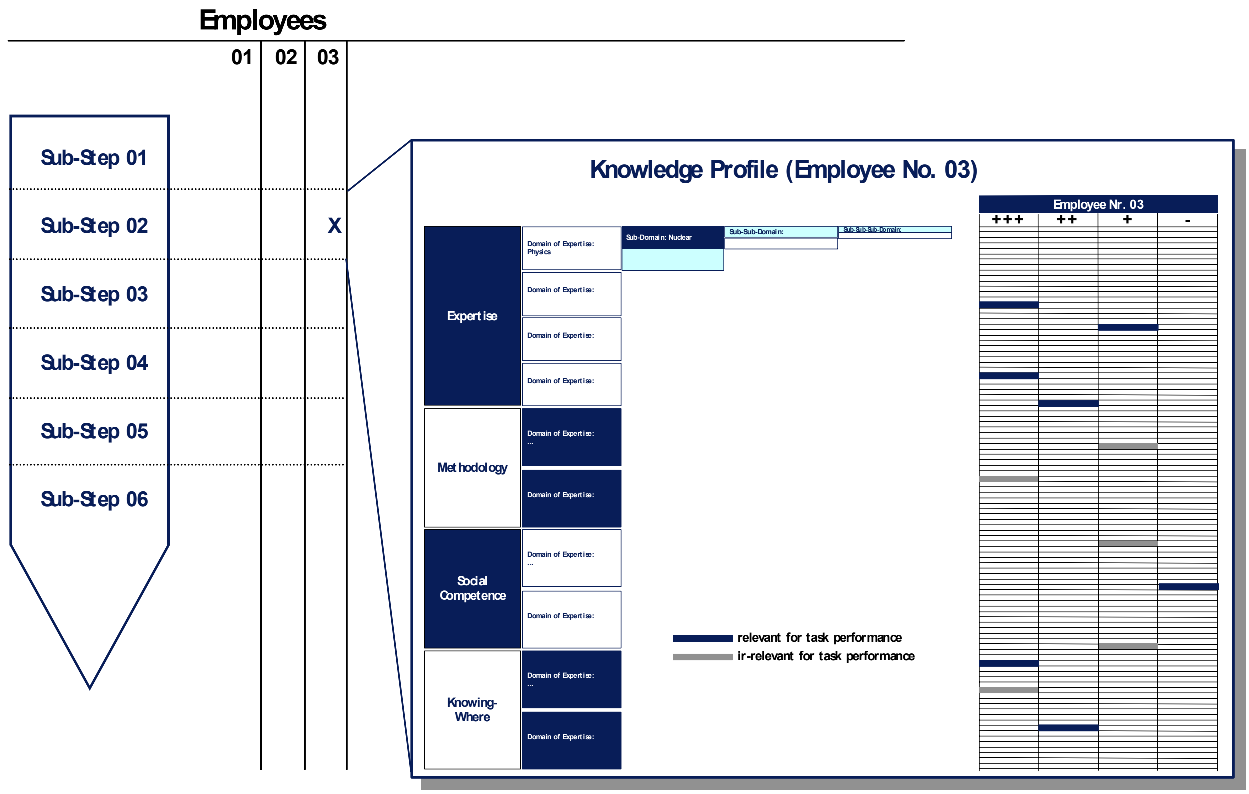
For those power plants that have identified and described their processes well, these first steps can be done within a rather short time frame. The next step will prove to be more time consuming. Now, the necessary knowledge bases to perform a certain process step have to be identified. This can prove extremely difficult as the employee involved may not even know why he/she is able to do certain things (so-called tacit knowledge). Nevertheless, there is no alternative.

Once, the various knowledge bases are identified, their importance to achieving the process output are identified. This is best achieved by close cooperation between the process owner and the employee himself/herself. Often enough, an employee's colleagues may also be able to indicate why only their colleague is able to achieve the process outputs and what skills differentiate him from others.

As a result of this analysis a knowledge profile (or: knowledge fact sheet) can be developed. Herein one can easily see which knowledge base contributes to which extent to the process performance of the employee (see figure D8).[3]

[3] Of course, an employee might not be willing to share this information when he/she is afraid to be substituted by employees who ask for lower wages.

Figure D8: Employee knowledge fact sheet in relation to a process sub-step[4]



Based on the knowledge profile a person-specific knowledge preservation strategy can be developed. However, it should not be forgotten that the expert may also contribute to other processes and his/her knowledge may also be critical to those. Thus, only after analyzing all processes and all sub-level process steps the knowledge profile for one expert will be complete.

While different knowledge bases may contribute to the expert's performance, it is not the single knowledge base that differentiates the expert from a novice. Rather, it is the expert's ability to flexibly integrate those knowledge bases in doing his job. Thus, a successor must not only master the various knowledge bases, he/she must also be able to integrate them.

Transferring knowledge can turn out to be a rather difficult task. Its difficulty is based on the tacitness of knowledge and its owner's inability to articulate such knowledge. Tacit knowledge is almost never acquired through education (at whatever level). Rather, tacit knowledge is the result of practicing knowledge. The more certain knowledge is practiced (i.e. turned from mental modeling into real action), the more a person is cognitively freed from monitoring each single step towards the achievement of an objective. While a novice thoughtfully switches gears when he/she starts learning to drive a car, later on the experienced driver does not need to think about when to switch. He/she simply does it, without consciously thinking what is to do. Learning to drive cannot be learned (at least not today) by doing desk research and doing to a driving simulation on the computer. It needs the real practice of driving a car and to learn in a real-world situation what can be done, should be done and not be done.

4 +++ within the knowledge fact sheets means that this knowledge is of utmost importance while '-' means that this kind of the expert's knowledge is not relevant to the task.

The more embrained and unconscious such knowledge is, the more difficult it is to articulate. Certain techniques may help to surface it again. However, there is no guarantee for that and thus tacit knowledge represents a major barrier to preserving and/or transferring knowledge. While explicit knowledge that can be put on paper and then get easily transferred, tacit knowledge requires close interaction between knowledge owner (sender) and a novice (less experienced person). However, we will discuss those issues in the next chapter.

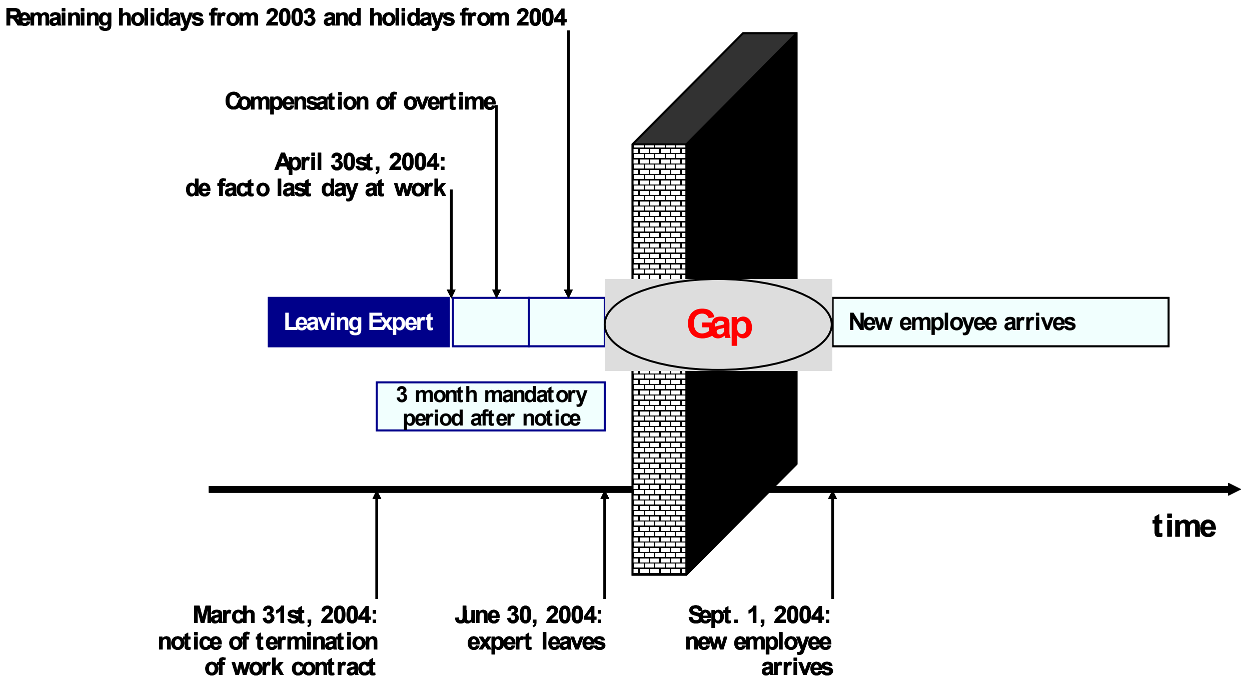
6. Knowledge preservation: Developing learning packages

While knowledge preservation methods vary considerably, the objective remains the same: to transfer the sender's capability for effective action to the successor/recipient. This objective is achieved when the successor has developed a knowledge base that will allow him/her to achieve the same qualitative level of action as the expert.

Still, knowledge is often poorly understood by management and thus compared to the complexity of knowledge transfer largely underestimated. Transferring knowledge often is perceived as an easy task. This assumption is reflected by two American researchers who investigated the transfer of technological knowledge. They state that management thinks that "you can just tie it (the technology; S. K.) up in a package, and I could just hand it to you; I would then forget about it, and you would open the package and say Wonderful. It just doesn't happen that way" (Gibson and Rogers, 1994).

The transfer of knowledge is a demanding process. It addresses the cognitive skills of both sender (teacher) and receiver/recipient (student). The sender has to take into account the student's cognitive abilities and absorptive capacity[5]. Of course, direct interaction between both parties is beneficial in such a situation. In reality experts and their successors often do not meet. When experts leave their successors are often not found and they start their new job sometimes long after the expert has left.

Figure E1: Typical situation of attrition in a Swiss firm.



Knowledge preservation activities have to take into account that an overlap is rather an exception. This means that often personal collaboration between the expert and his/her successor will not be possible. But also in situations where collaboration is possible one challenge remains: how should the expert's knowledge be transferred effectively to the successor? This section addresses this challenge and provides a framework for effective transfers of knowledge to successors.

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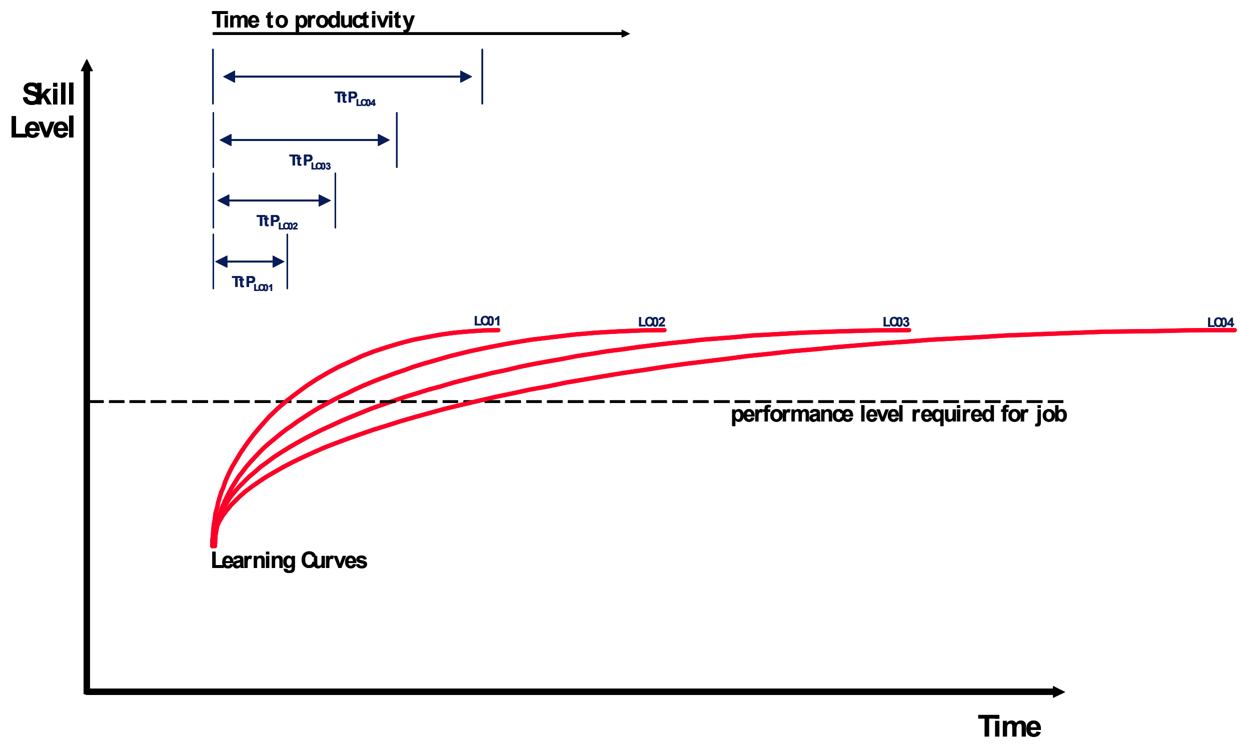
5 The term absorptive capacity was created by Cohen and Levinthal (1990). Simply put this term stands for a person's or organization's cognitive ability to assimilate and deploy new information/knowledge.

Depending on a successor's previous knowledge (i.e. absorptive capacity) and learning ability the time to develop expertise may vary considerably. As shown in figure E2 the difference in time to productivity (TtP) between learning curve 01 and learning curve 04 can vary considerably. From an organization's perspective, the time to productivity (or even skill level) is critical: either a certain task cannot be done or its completion demands more time and thus more resources than foreseen. This is the conclusion of what has been observed with Swiss Federal Nuclear Inspectorate. In cases of attrition the work on certain subjects never dropped to zero. Successors often were intelligent and bright people. Yet they were not familiar with the governmental environment, and thus work proceeded slower (in the beginning) or needed additional input.

However, when the introduction of a successor is well planned, the learning curve can get compressed considerably and the necessary skill level is reached much faster. While it can be assumed that learning curve 04 represents a situation where a successor has to work largely by his/her own without much help from others or his/her predecessor, the steeper learning curve 01 clearly indicates not only good cognitive abilities but also a well prepared learning package for the successor. Thus time to productivity depends on two factors: the cognitive abilities of the successor and the quality of knowledge preservation activities (i.e. the quality of the learning package / knowledge transfer).

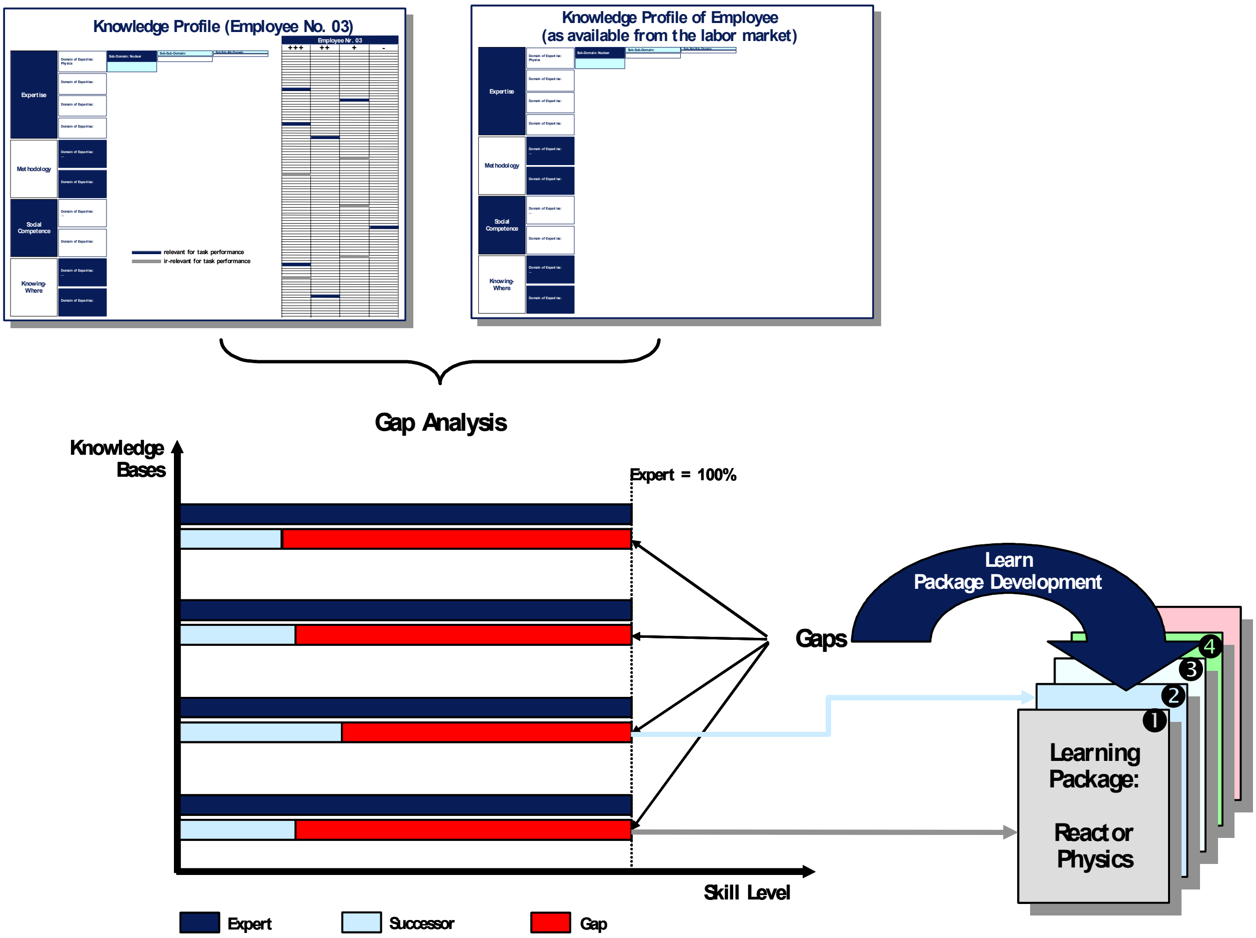
Figure E2: Time to productity (TtP) in relation to an individual's learning curve.



Thus, the question arises: how can we help a successor to compress his/her learning curve? While we cannot just hand over a pill that improves the successor learning abilities, we can provide good learning packages that support the successor in the best possible way.

In order to compress the learning curve the content of learning has to be tailored to the learner's needs. Thus knowledge preservation has to bear in mind the probable cognitive skills of those employees that are available from the labor market. Those skill levels will – normally – not stand the comparison to those of experts in the area. So it is best to sketch a probable knowledge profile of the successor and match the learning activities to this profile. This gap analysis is illustrated in figure E3.

Figure E3: Skill gap analysis and development of learning packages.



The size of gap decides the structuring of the learning package. The size of the gap depends on what average qualification is available from the market: when the qualification is rather low the gap will be large while the gap will be small when average qualification is high. Of course, there is still the danger that the successor hired may not even match the average job criteria. This might be the situation in times of economic prosperity while in times of economic recession the qualification of the workforce available from the labor market might exceed the average knowledge profile.[6]

The gaps identified between the expert's skill level and the average skill level of the workforce now has to be translated into learning packages. This translation is often done by people involved in the process of managing knowledge transfers in situations of attrition – at least, this is the experience with the Swiss Federal Nuclear Inspectorate. It can be observed that the people involved in those processes do those translations diligently and carefully. They design learning packages that respect the successors'

[6] There is one restriction that applies here: it is assumed that the successor has the same basic qualification as his predecessor. E.g. the expert was a nuclear physicist when hired, it is assumed that another nuclear physicist can be hired from the labor market. If it is not possible to hire a nuclear physicist, the learning package would have to be designed in accordance to the knowledge profile of – let's say – an average physicist.

previous knowledge. They provide the documents that are helpful. And they assign the successors to those tasks that can be executed with the successor's previous knowledge. And, last but not least, successors are directed to those tasks that provide fast learning.

It should be highlighted that application of what is learned is critical to develop a knowledge base. Without practice the successor may develop what one might call "theoretical knowledge": he/she might be able to explain why something should be done. Yet, in critical situations, this person might fail because he/she lacks the experience of deploying the knowledge in a real situation. Learning packages thus must include times of practicing knowledge.

In a first step, the expert (and e.g. his supervisor) identify the critical knowledge of a process step or (sub-)task as mentioned previously (see figure C10, page 14). Based on what can be generally expected from an average successor, they define how to connect the expert's knowledge base with the successor's. This first step is very important for the progress of the learning process. If the successor's knowledge base is not successfully connected to the expert's knowledge base, learning might not even happen and the successor could even decide to leave the organization out of frustration.

Let's have a look into one of the learning packages that the author of this report experienced when he joined Swiss Federal Institute of Technology (Zurich) as a research assistant at the Institute of Industrial Engineering several years ago. Besides the objective of writing a Ph.D. dissertation, a research assistant has several tasks to do. He/she has to coach students when they do their project and diploma theses. Coaching this process is more difficult than it can be assumed as all the theses are practice-oriented and thus take place in industrial organizations. And all theses have to follow the principles of a methodology called Systems Engineering (SE).

To ensure the methodological knowledge, new assistants are sent to a five day Systems Engineering seminar before they are appointed coaches for student project or diploma theses. After the seminar, the Systems Engineering thinking is deployed with the first project thesis.

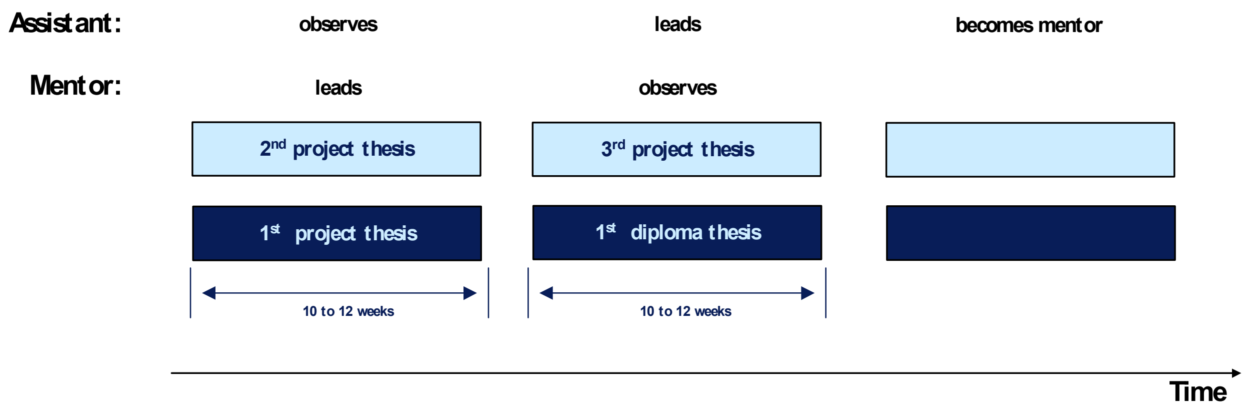
To start with a project thesis means that an organization has to be found where the thesis can be done. Thus industrial partner identification is the first step a new assistant should learn. Normally, a new assistant inherits some of the business contacts of the more experienced assistants and can tap those sources easily. Thus, close cooperation between the new and the older assistants is important in the beginning. This is ensured by a mentoring partnership between an older assistant (normally one at the end of the assistant life cycle) and the new assistant.

Next, when the company has been successfully contacted, the topic of the thesis has to be identified. Often enough, people in organizations are not completely aware what the real problem is and why things are not running as they should. As new assistants normally do not have business experience, the mentor plays a critical role and the new assistant attentively (hopefully) observes the discussion between the organization's representatives and his/her mentor. Based on this discussion a task description is later on elaborated. This has to be done by the new assistant. Later on, the document is discussed with the mentor who informs what corrections/modifications are necessary and why. The document then is sent to the organization's representative and signed. Later on, the document will also be signed by the university supervisor.

After two to three weeks in the thesis, a first presentation takes place. Here, our new assistant learns how he/she can provide the student valuable feedback regarding the work he/she has already done and what the next steps will be. In the very first assignment, the mentor is playing the lead role and the new assistant is observing and contributing according to his/her knowledge. Overall, there are three presentations, including a final one with the supervisor. When the project thesis is over, a report has to be analyzed. The students will receive a detailed appraisal and a mark. It is again up to the new assistant to write the appraisal and to suggest what mark the student will get. The document is discussed with the mentor and the new assistant gets feedback.

For the next project thesis, the roles between our now not-so- new- anymore- assistant and the mentor are slightly changing. Now the assistant is taking the lead when a company is contacted and he/she also takes the lead during the elicitation of the organization's problem. The task description is again discussed with the mentor. During the presentations the mentor now takes over the observing role and provides additional feedback – whenever necessary. In the end, the assistant writes the appraisal and suggests the mark for the student. The mentor provides his view on the thesis and both discuss where modifications to the appraisal and mark are necessary. This also represents the end of the assistant-mentor-relationship. Figure E4 summarizes the learning process.

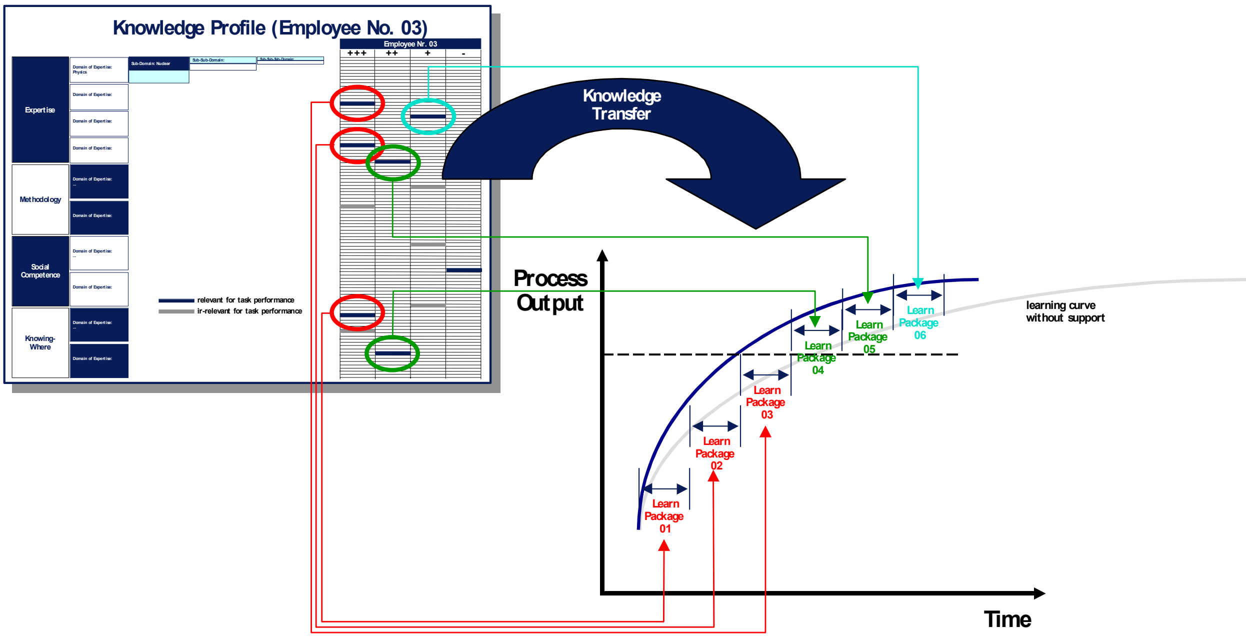
Figure E4: Tandem between new assistant and experienced assistant at ETH Zurich.



From the author's perspective, this knowledge transfer was successful. In other instances transfer often did not take place or was incomplete. The result was inactivity in certain areas and considerably longer times to productivity.

Each learning package has to include milestones and to provide the information through which activities the successor can strengthen his/her knowledge base. Further more, the learning package clearly has to differentiate between tacit and explicit knowledge. Some expert activities may only be learned by close collaboration where the expert might say: "watch me". Only a good designed learning package allows an organization to compress the successor's learning curve as illustrated in figure E5.

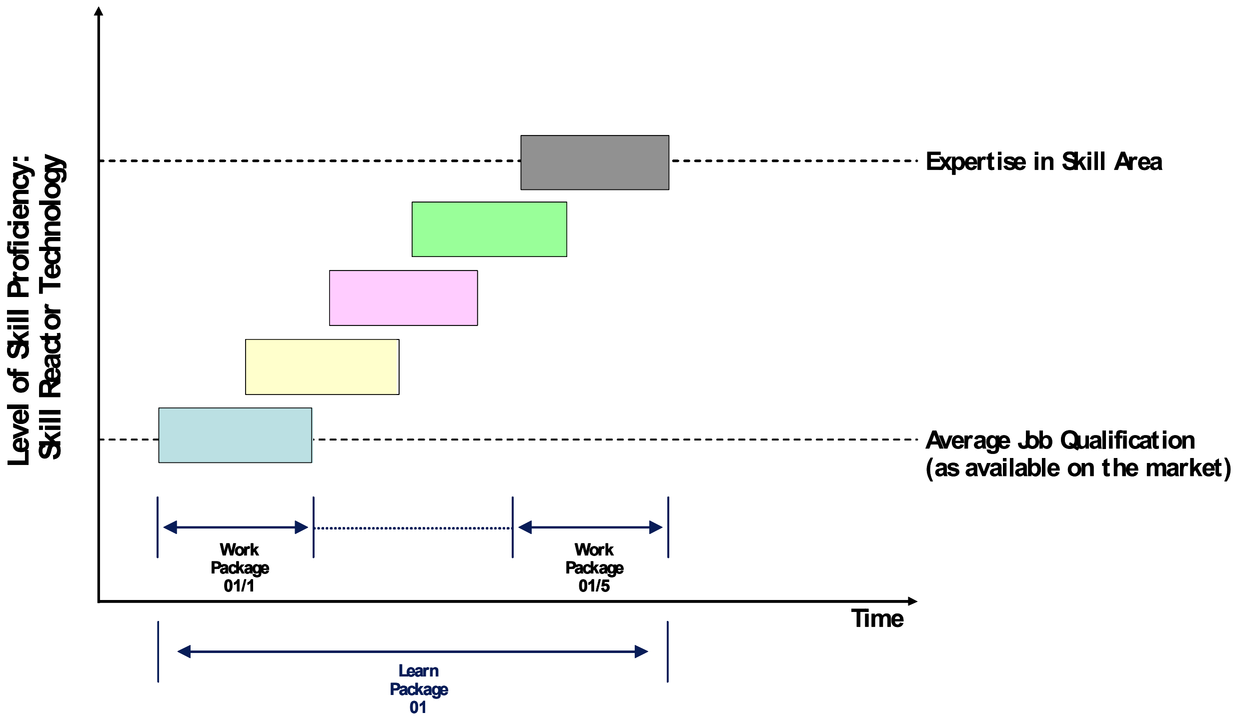
Figure E5: Compression of learning curve by the means of learning packages.



Within the various learning packages there is a clear hierarchy: First of all, those packages are developed that are critical to a task's or process step's performance. Then, when the transfer is initiated, those prioritized packages represent the very start of the successor's learning activities. It depends on the successor's first tasks and duties which learning package will – in the end – have to be assimilated first.

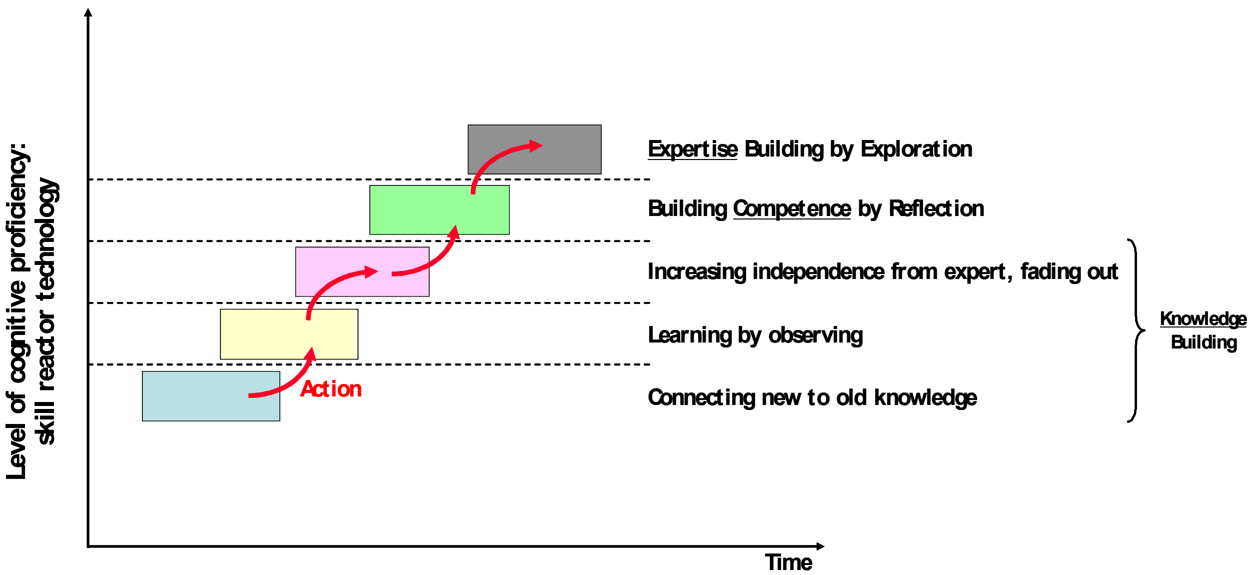
The development of learning packages has to address the needs of learners. Thus, the behaviors of adult learners and their preferences have to be taken into account. Adults prefer different learning styles compared to pupils or students. Starting from a skill level that can be assumed as being given on the labor market, knowledge is built up through the means of teaching and learning by observing (see figure E6). The longer the learning lasts the more the expert's support is fading. *The expert never must provide solutions*. Rather he points the student to interesting points and facts and thus allows the construction of mental models that are directed towards the same objectives yet as much as possible independent from the knowledge's source.

Figure E6: Designing the learning package for skill building.



In order to avoid inactive knowledge, the information assimilated has to be turned into actionable knowledge. Therefore, learning needs considerable practice opportunities. Practice sessions are important and helpful at the same time (see figure E7). In the end of this process, the successor (we assume that the necessary cognitive skills are available) disposes of what can be called expertise. Building expertise from basic skills may take days in simple cases and years in others.

Figure E7: Expertise can only be acquired by practice.



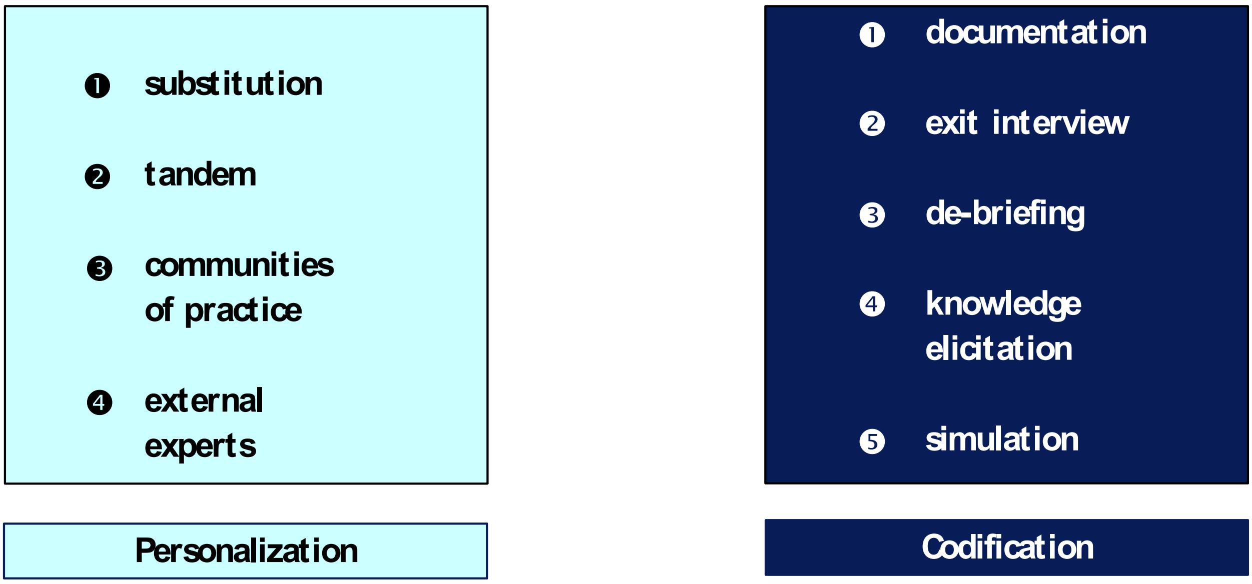
7. Preservation strategies

There is a considerable amount of strategies to preserve knowledge. Primarily, the activities to be deployed largely depend on the nature of knowledge: tacit knowledge requires greater efforts to preserve knowledge than explicit knowledge. While tacit knowledge can be preserved only by transferring it to successors or simply other people (so-called personalization strategy), explicit knowledge benefits from the possibility of codification (articulation) and its storage with the help of advanced information and communication technologies.

Preserving tacit knowledge equals to transferring tacit knowledge to other employees[7] or to engage in a knowledge transformation process that transforms tacit knowledge to explicit knowledge. Such endeavors are highly time consuming. In literature well-known Japanese authors Nonaka and Takeuchi (1995) present an example of such a conversion along the development of a breadmaking machine developed by Matsushita. During the development of the machine it took an engineer around half a year to come up with a description (algorithm) how dough has to be manipulated to create a good quality of bread. Other examples are given by Davenport and Prusak (1998) for automating flight procedures in airplanes (2 years) and by von Krogh et al. (2000) for a chicken deboning machine (7 years).

Generally, two categories of knowledge preservation strategies (activities) can be discerned (see also Figure F1): personalization strategies (knowledge transfer) and codification strategies (knowledge articulation/elicitation).

Figure F1: Survey of knowledge preservation activities.



Personalization strategies have several advantages: as a direct contact between the sender (leaving employee) and recipient (successor) is established, the transfer provides the opportunity to include *feedback loops* into the successor's learning. Things that are not easy to be understood can be explained in more detail. Certainly, such

[7] One of the biggest barriers in transferring knowledge between an expert and a novice are cultural differences between both of them. While younger employees generally benefit from advances in science and the integration of such advances in the university education, the aging expert has gathered a lot of experience that can provide superior to anything the novice knows.

close cooperation and collaboration bears the danger of conflict and thus both sides – sender and recipient – have to get well prepared for this endeavor. One other major disadvantage is the aspect of costs: employing two persons for the same "job" over a certain amount of time is not efficient. Such a solution will thus only be selected when either the knowledge to be transferred is very important to the firm or the firm (more or less) enjoys a monopolistic situation which reduces the pressure of competition.

Codification strategies shine where personalization strategies are weak: they are efficient from a transaction point of view. Knowledge is stored (i.e. transferred to some kind of "document" [e.g. file, video tape, etc.]) and can easily be distributed to anybody in search for this knowledge. Also, interpersonal conflicts are not an issue. There is, however, one great disadvantage. Documents are normally developed with the developer's needs in mind. They are not created for third parties. They are created because of reduced reliability of the human brain to remember. They are created to avoid the loss of certain elements of an individual's capacity for effective action. So documents are created to allow – later on – a more or less complete reconstruction of the original situation (and thus capability for effective action). To create documents with the needs of unknown users in mind poses considerable difficulties that are not easy to overcome. Or, if they are overcome, the codification solution is no longer as efficient as it was intended.

7.1. Personalization strategies

Substitution

Developing or installing a substitute can often be considered to be one of the best activities for knowledge preservation. The Swiss Federal Nuclear Safety Inspectorate has deployed a very sophisticated substitution regime. Often enough, substitutes share the same office and thus learn the expert's skills continuously.

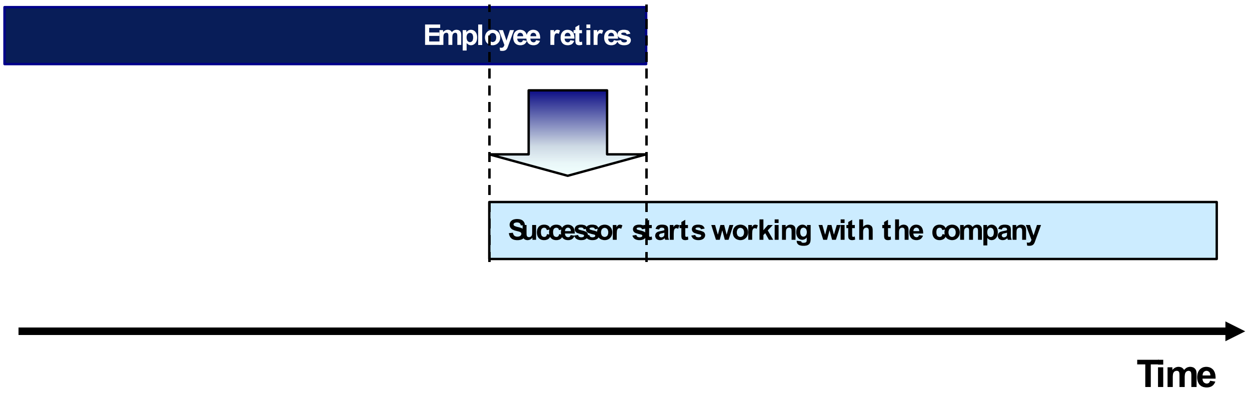
From a technical point of view the installation of a substitution regime can be called in indirect measure for knowledge preservation. Knowledge preservation is the result of having two people doing the same thing and being able to replace each other at around 100 percent. So knowledge preservation is the result of redundancy.

However, due to economic pressures substitutes are often considered to be expensive (and unnecessary redundancy) and thus can rather be found in governmental institutions than in private organizations.

Tandem

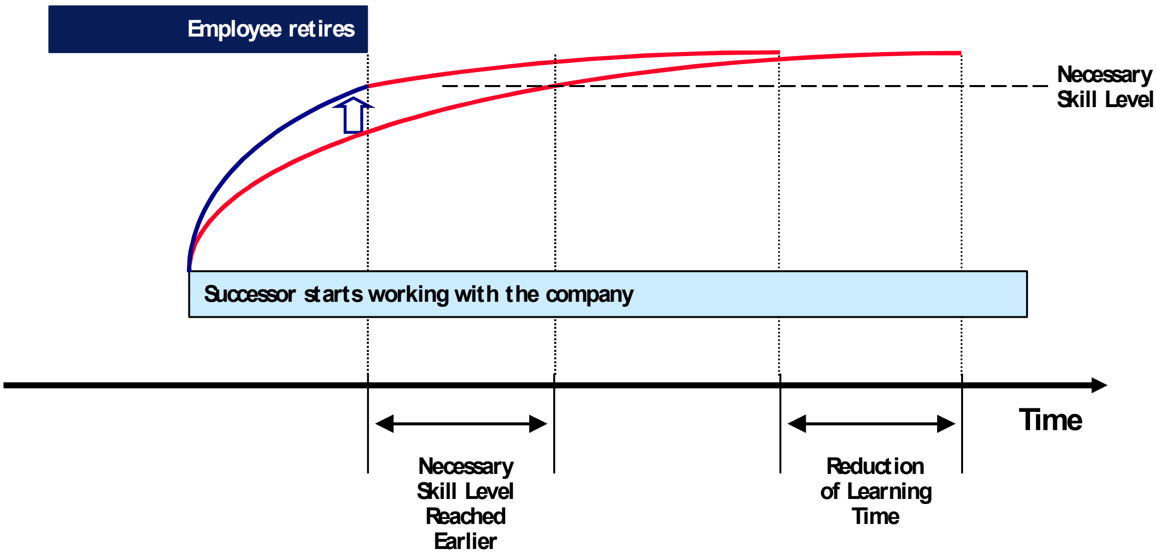
Preserving knowledge by using a tandem means a temporal cooperation and collaboration between an expert and his/her successor. For a certain period of time, both people work very closely together and – as a result of this cooperation – the successor step by step acquires the necessary skills to perform the expert's tasks. The tandem principle is illustrated by figure F2.

Figure F2: Tandem



Basically, the tandem is a dynamic construction for the means of knowledge preservation. Strictly speaking, a tandem is not a knowledge preservation activity but rather a knowledge transfer activity as knowledge is transfer from one and rebuilt by another person. With the help of the expert the successor can compress his/her learning curve and thus achieve the critical skill level considerably earlier than without the expert's help (figure F3).

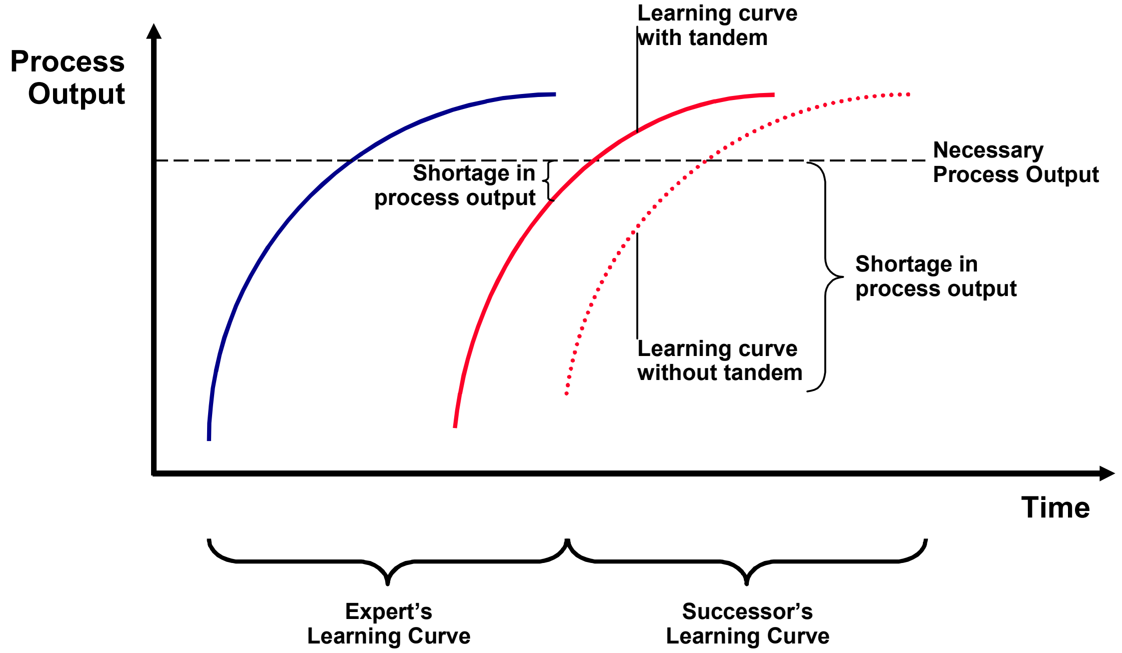
Figure F3: Compression of the learning curve in tandem knowledge transfers.



As figure F4 will illustrate, an ideal[8] tandem situation with an overlap between an expert and his/successor is generally beneficial. Without the overlap the necessary process output is not given for a certain amount of time. This might not be harmful during the times of normal operation in a NPP. However, in situations of crisis (incidents) such a knowledge gap can become disastrous.

[8] → i.e. mainly a good "chemistry" between the mentor and the successor.

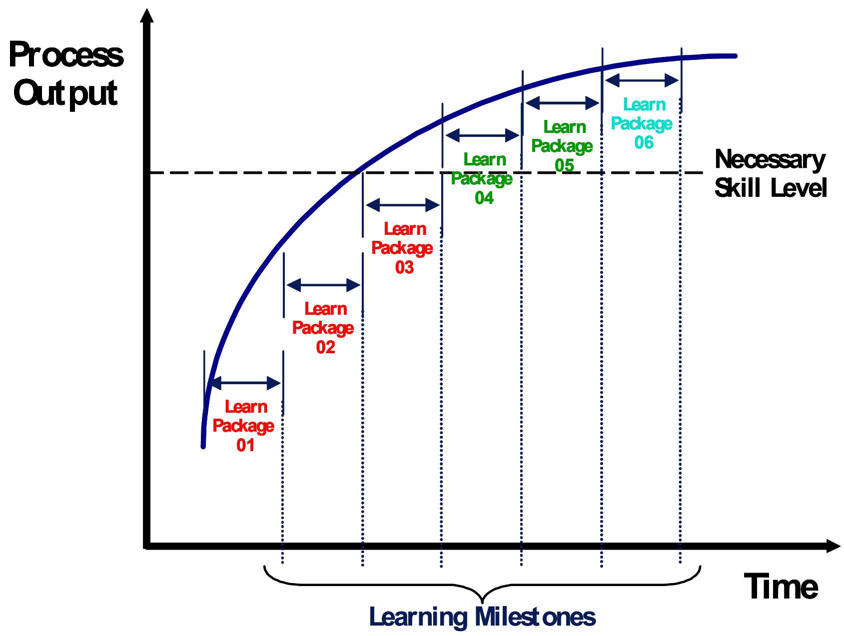
Figure F4: Effects of attrition to process output with/without tandem



Experience from Swiss NPPs show an extreme disposition towards the adoption of the tandem to ensure smooth operation and securing the necessary process output levels. In some NPPs tandems stretch over an eight year period (including all the successor's learning activities). This, however, is only possible in a situation of financial prosperity. In other countries, cost saving activities do exclude such long times of overlap.

For the tandem to provide an ideal learning opportunity, the chemistry between the people involved has to be alright. Often enough, successors dispose of diverging frames of references and think differently compared to the experts. It does not take a lot to enrage an expert when he/she thinks that his/her knowledge is not respected by his/her successor.

Figure F5: Setting milestones for learning/knowledge transfer control.



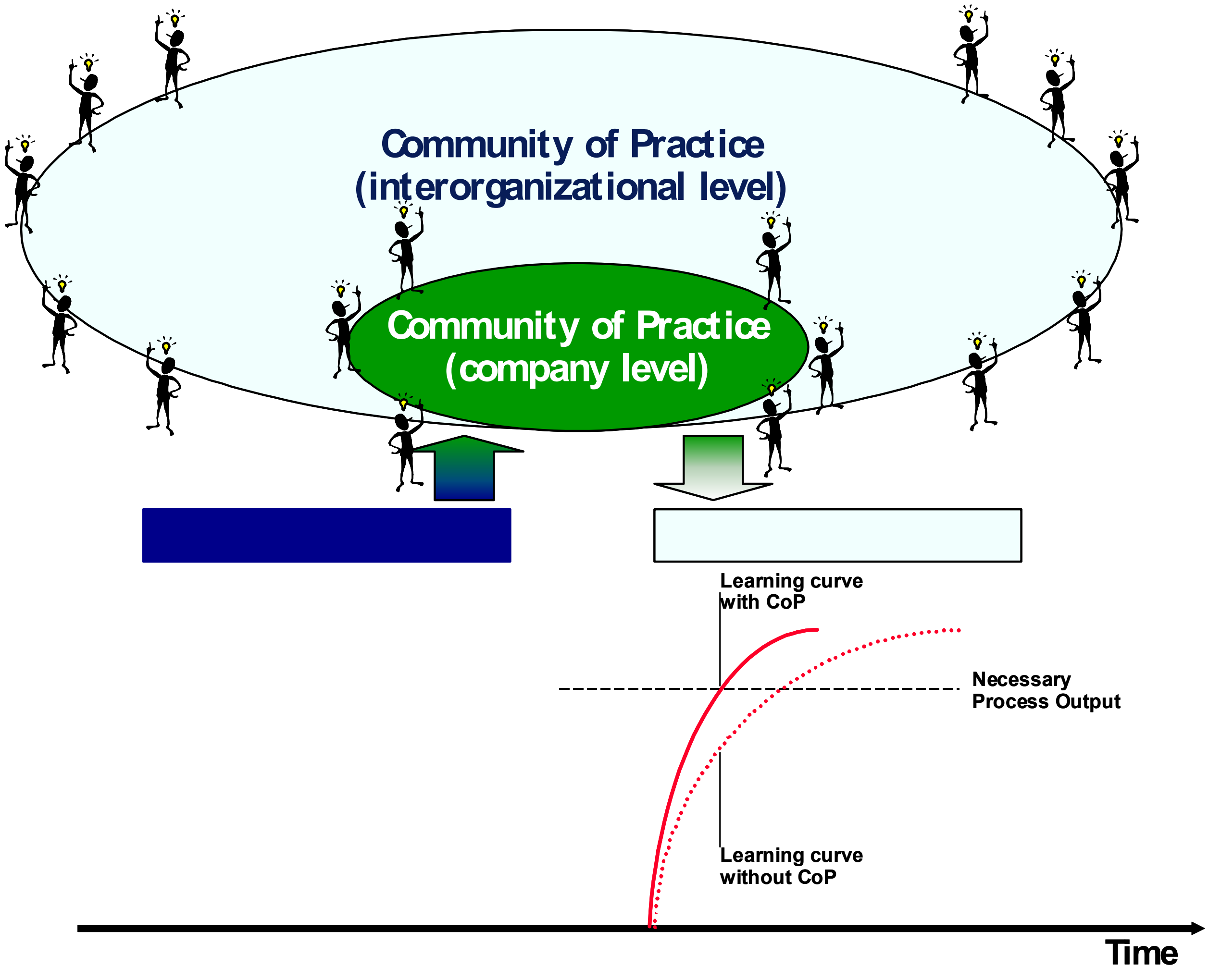
Thus, for a tandem to fulfil the expectations it is necessary to prepare both parties involved – the expert as well as the successor – to the joint endeavor. Here NPPs can tap the literature on intercultural learning. Furthermore, tensions can be reduced when superiors get involved into the process and both – the expert as well as the successor – has to report the progress of the collaboration. Such reporting should be directly related to the milestones within the learning program of the successor (see figure F5).

Appendix A explains in detail how the tandem has to be designed to make the successor's learning as successful as possible.

Communities of practice

Recently, communities of practice have received a lot of attention within firms as well as academia (e.g. Wenger, McDermott and Snyder, 2002). Some people even communities of practice (CoPs) consider them as the backbone for knowledge management. This aspect of communities of practice is of minor importance to this study as the main topic here is knowledge preservation and not knowledge management. Here we focus on the community of practice's ability to serve as a dynamic storage bin for a company's knowledge.

Figure F6: CoP memberships (on intra- and interorganizational levels) help compressing the learning curve.



CoPs develop when people convene that share a similar activity within a firm. However, communities of practice do not restrict themselves to intra-organizational membership but often extend beyond company boundaries. This is the main reason for including communities of practice as a means to preserve knowledge for NPPs.

Supposing that pressurized water reactors (PWRs) have many things in common, it makes considerable sense for (even competing) firms to allow members of its staff to share knowledge. The larger the network (community) is the more experienced it will generally be. The more experience it has the more valuable it is to the participating firms as well as individuals.

When a community of practice exists, an expert's successor can tap the community's knowledge to compress his/her learning curve (see figure F6). Of course, it becomes important to differentiate between company level and inter-organizational level CoPs. Company level CoPs are designed with knowledge sharing and transferring as the focal activity. They exist either because the organization's management has initiated them or is supporting them with considerable resources. Still, CoP membership is not always seen welcome with supervisor.

Whenever necessary he sends an email/fax or simply picks up the phone and dials the number of that community member that he/she thinks can help most. Normally, CoP members are loyal to the community and help each other based on the principle of generalized reciprocity. That means: helping is not oriented towards a single CoP member (and thus not a favor).

CoPs at the inter-organizational level are a different story. Here, tapping a CoP member's knowledge who works for a different company is more difficult. The two persons may work for competing organizations and superiors may keep an [attentive] eye on such activity because they fear the loss of trade secrets or proprietary knowledge. Thus knowledge may flow well between the members of an inter-organizational level CoP in those instances where enabling activities are concerned. However, knowledge that affects an organization's competitive position will not be easily and freely shared.

There is, of course, a major difference between the knowledge transfer that takes place within a tandem and a CoP. CoPs are voluntary and members cannot be commanded to help. While the expert during the tandem is mandated to help, the help of a CoP member is dependent on this person's ability (skill, time) and willingness to help.

A practical example of community of practice in the nuclear industry is the Young Generation Network whose name later was changed into *International Youth Nuclear Congress* (IYNC).[9] In its mission statement the IYNC declares knowledge preservation as one of its key objectives: "Transfer knowledge from the current generation of leading scientists to the next generation and across international boundaries". To achieve this objective, there is now a bi-annual world-wide conference organized that promotes knowledge sharing amoung younger members of the nuclear industry.

[9] see http://www.iync.org for more information.

External Experts

In many instances NPPs will find out that expertise necessary to produce process output can – at least partially – be found outside of its boundaries. Whenever critical knowledge exists it is useful to identify external sources of expertise in order to prevent desaster when an expert's knowledge would be needed but he/she is not available.

Such experts can be found in areas that may not even be directly related to the nuclear industry. Wölfel (2002) illustrates that knowledge which was originally developed for the nuclear industry was developed further outside of the nuclear domain because people involved in the creation of this knowledge lacked opportunities to deploy this knowledge within the nuclear industry. Thus, knowledge found new applications outside of the nuclear industry. Sometimes all relations to the nuclear industry collapsed and firms exited the nuclear business to engage in more promising activities. Yet, the knowledge is still there.

In Switzerland, Swiss Federal Nuclear Inspectorate heavily deploys external experts to get its work done. As the organization has not as many employees as necessary to fulfil its duties, external experts contribute where internal resources are not available. In those situations, internal experts allocate work packages to those external experts and supervise their activities and work results.

In one area, a successor only was found several months after an employee had retired. During that time, the former employee still supported the Inspectorate's activities. Yet, without the help of an external engineering company the workload could not have been managed. To ensure the continued external support the contractor was forced to sign an agreement that creates an internal backup inside of the engineering firm.

To prevent taks/gaps in process outputs, external experts have to be continuously available. If internal backups are not possible, agreements with external experts should be concluded that ensure access to the external experts' knowledge in situations where internal experts are not available.

External experts, of course, can also be former members of the organization – whether they now work for a different company or have retired. An interesting solution to prevent the loss of knowledge as a result of retirement has been developed by ABB, the Swedish-Swiss-based firm. Formerly, the company financed a pool of senior executives (called ABB Consulting Ltd) that had reached the age of retirement but was considered to be too good (or too valuable) to simply be sent away. Thus, similar to a tandem situation, those executies served as mentors to younger executives and shared their insights with them.

Recently, ABB has founded a separate entity called Consenec. Effective January 1, 2003, ABB Consulting Ltd changed its name to Consenec Ltd – Consulting by Senior Executives. Consenec allows senior managers from ABB (and today due to selling parts of the company to Alstom and Bombardier) and Alstom and Bombardier to withdraw from their active business life step by step and it furthers the know how and experience transfer.[10]

[10] More information is available at http://www.consenec.ch.

Of course, external experts cannot be relied on all a NPP's activities. Whenever an individual's *knowledge is time critical*, i.e. certain events call for immediate action, external experts are not a viable solution. Except from the situation that the external experts are located within the organization's own premises, the use of external experts is normally limited to non time critical activities.

7.2. Codification strategies

Documentation

As with all knowledge workers, documentation is a word that is far from being loved. Engineers, for example, do not like to write down things. They prefer to act or to show but not to write.

Forcing knowledge workers to create documents that illustrate their activities is resisted with reference to the lack of time to do it. Thus, documentation is often more wish than reality. In some companies knowledge workers even threaten their superiors to leave the firm when they are forced to spend more time on documentation.

Further more, documentation is always subject to one major problem of information management: Often enough, important information (i.e. documentation) cannot be found as people in need of the information do not know where it is stored.

To make documentation work employees need incentives to do the documentation. As long as incentives are offered, knowledge workers may be willing to substitute their free time with documentation activities. However, lessons from various firms clearly indicate that as soon as the incentives for documentation are withdrawn the employees' willingness do document rapidly decreases.

Exit interview

For many years, the Swedish-Swiss-based electrotechnical company ABB – a former supplier to the nuclear industry – has been doing exit interviews with people that left the company. An important part of those interviews was the capturing of knowledge. To do so, the company developed a series of forms that were to filled out by a facilitator who was leading the knowledge capturing session.

In the nuclear industry knowledge capturing was pioneered by the Tennessee Valley Authority (http://www.tva.org). Generally, the US has often preceded European countries and firms regarding the preservation of knowledge. This is the impression based on the benchmarking exercise done by APQC in their 2001/2002 study. Among the best practice firms there were four US-based firms/organizations (Northrop Grumman, Corning, Tennessee Valley Authority, and the World Bank), one Canadian Company (Bank of Montreal) and just one European Company (Siemens AG).

When the approaches of those best-practice companies are compared, exit interviews quickly emerge as the de-facto standard for knowledge preservation in those companies. Normally, a knowledge capturing-oriented exit interview proceeds as follows:

1. A person with knowledge in the field of the person who retires/leaves the organization makes himself/herself familiar with the expert's situation. Depending on the interviewers knowledge this may take up to one week.
2. The expert is interviewed. The interview has several sections:[11]
   - ☐ Technical / scientific knowledge
   - ☐ Methodological knowledge (how are problems solved)
   - ☐ Social competence
   - ☐ Meta-knowledge[12]
3. The interview is analyzed. The information is brought in a format that can be communicated to people with non-expert knowledge.
4. The document is stored in the company's electronical/non-electonical archives.

Critical to the success of the exit interview is the interviewer's ability to elicit the expert's knowledge. Therefore, the interviewer *must NOT dispose of the same level of expertise as the expert*. This advice might sound counter-intuitive in the beginning. When two experts communicate, a lot of technical jargon will be used. This is just one aspect that will prevent the connecting between the successor's and the expert's knowledge base. Further more, the expert has a very deep knowledge within the domain of his/her expertise. It is highly difficult for the expert to "think down" to the successor's level. Yet, it is not only the inability to think down to the successor's level of knowledge that makes experts a bad choice for exit interviews.

As experts have a very large knowledge base, their notes to reconstruct some actions later on can be very short – yet still efficient. Remember figure A1: knowledge is context dependent. The experts know the context, they don't have to put it down on paper. What they put down makes sense to them. It will, however, not make sense to non-experts. Therefore it is highly recommended that the interviewer is someone who does not need to "think down" but who is representing the knowledge that can be expected to be representative for an average successor.

On the other hand, technical skills have to be present to create valuable documents. Without technical knowledge, the interview will take place at a too trivial level where important aspects cannot be discussed.[13]

De-Briefing

In many ways, a person's de-briefing resembles the exit interview. However, there is one important difference. De-briefings are not to be done in situations when an expert is leaving but rather as a continuous task during an expert is under contract. A person may be de-briefed several times during his/her stay with the company.

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[11] Expertise is normally the result of a persons ability to integrate technical/scientific knowledge, methodological knowledge, social competence and meta-knowledge (knowing where to find information/knowledge).

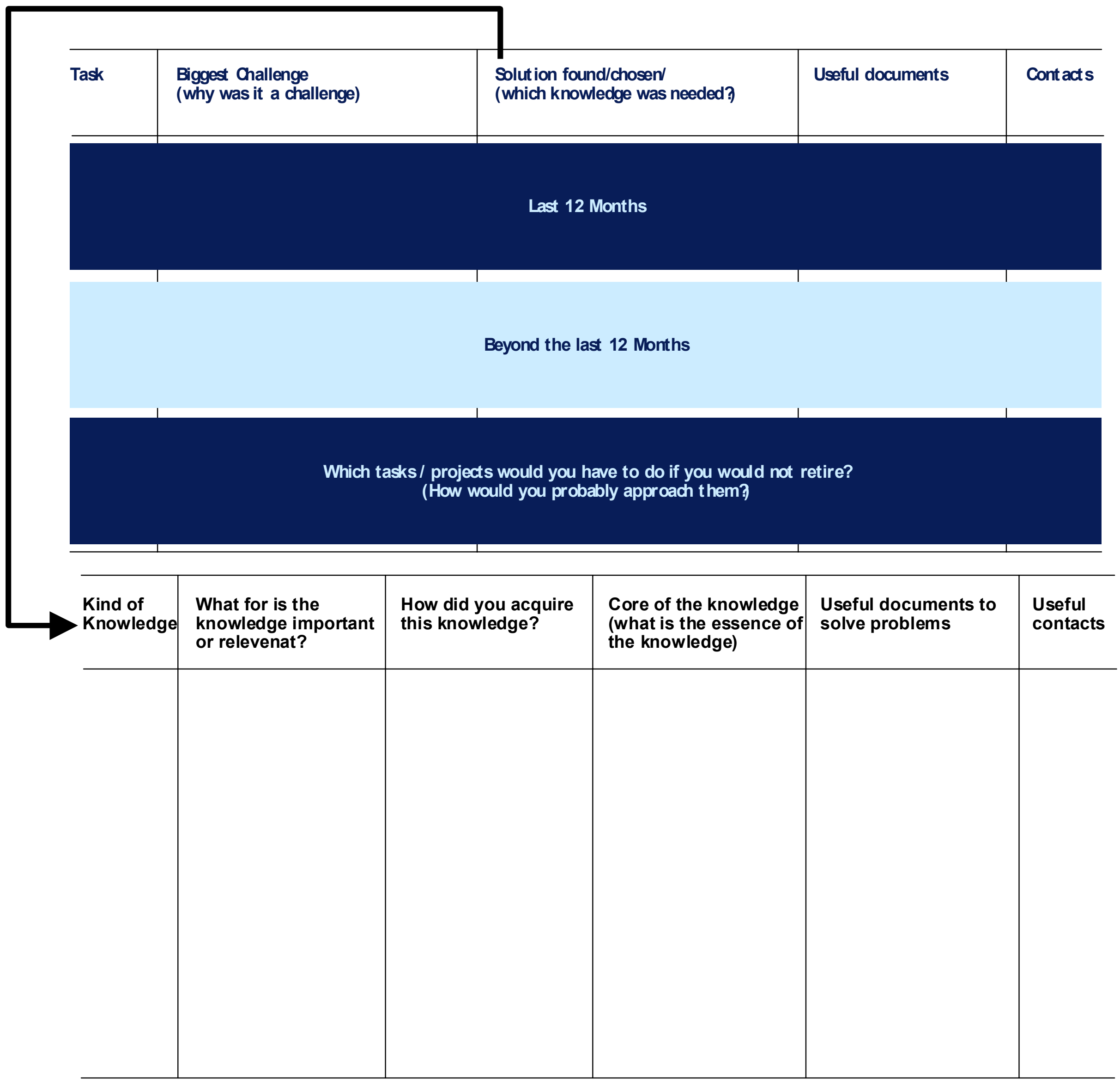
[12] Meta-knowledge is an individual's cognitive state of having the information where the individual can find the knowledge he/she needs to do his/her work.

[13] Based on personal interviews with representatives from Corning this company sends the interviewers to a local college to provide them the necessary journalistic skills. However, it is technical people who do the interviews.

To do a good de-briefing the interviewer needs to have the same skills as in the case of the exit interview. However, to produce good results it is recommended that the expert starts maintaining a daily journal (or log file). The reason for maintaining a daily journal is simple: the expert's knowledge gets visible by what he/she is doing. A daily log clearly provides an idea where the expert is deploying his/her knowledge. Thus it gets easier to identify what was necessary to be done to achieve the task/process output.

However, to prepare for the interview the log file has to be provided to the interviewer. Figure F7 firms can deploy forms similar to the one depicted in figure F6.

Figure F7: Forms for conducting an expert de-briefing.



Knowledge elicitation

As was previously indicated, knowledge elicitation is often considered to be the solution to many knowledge management problems. Ever since Japanese authors Nonaka and Takeuchi (1995) introduced their idea of the transformation of tacit knowledge to explicit knowledge, an overwhelming number of authors have joined their – unfortunately –

wrong view. Polanyi (1966) has clearly indicated that tacit knowledge is completely different from explicit knowledge, i.e. tacit knowledge cannot be easily converted into explicit knowledge.

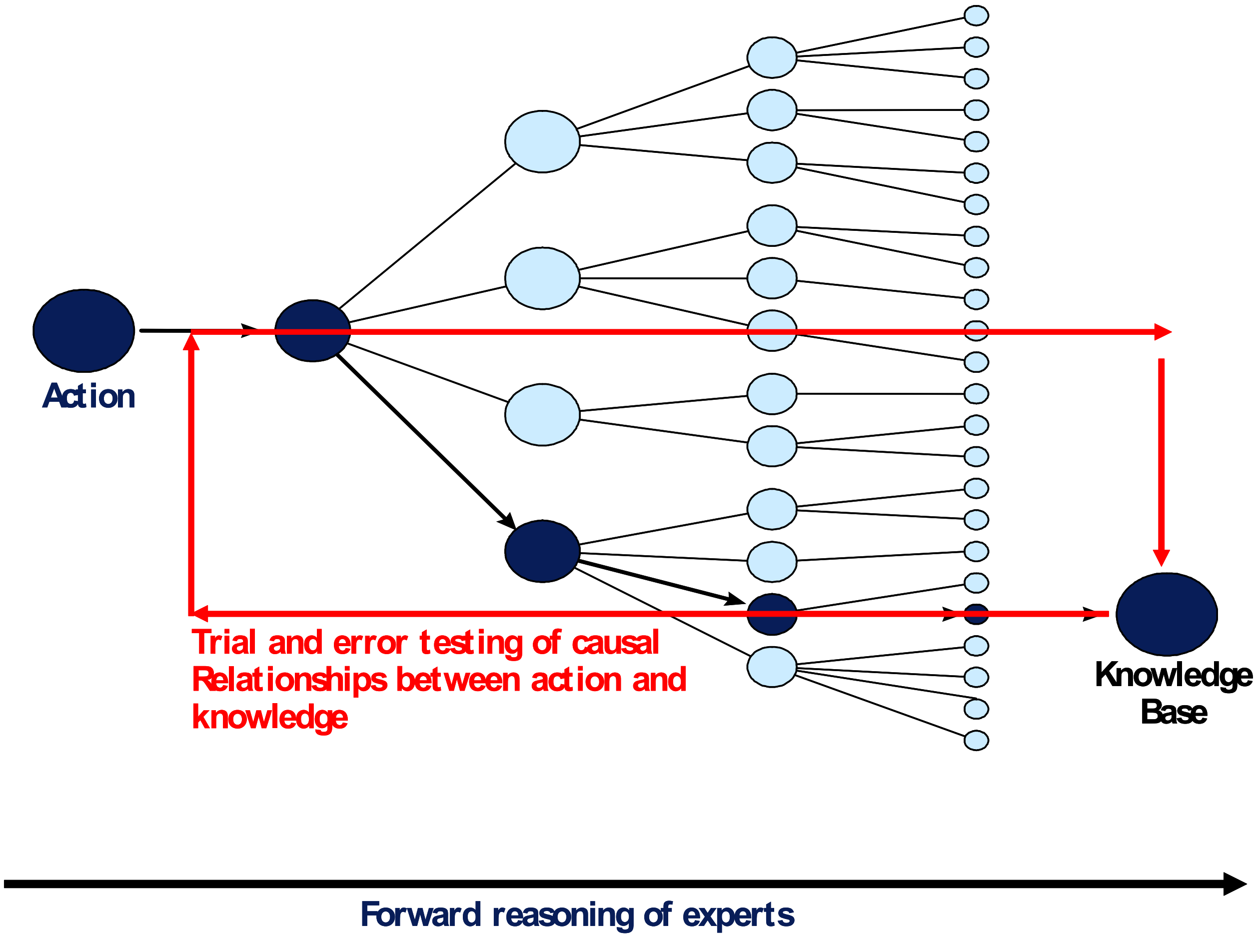
Knowledge deployed by people can be defined as those constructions of reality that help an individual to achieve his/her objectives. Those constructions are normally tacit, only in the case of novices those constructions are explicit. Unfortunately, those tacit constructions cannot – somehow – be transferred easily to the explicit domain. To bring a construction into the explicit domain the expert's knowledge has to be rebuilt from scratch in the explicit domain.

Such a rebuilding is the main reason why this "conversion process" takes a long time: it took a Matsushita engineer six months to come up with the metaphor of "twisting stretch" to describe how a baker in a famous Kobe hotel prepared the dough to get an excellent bread. And, also not to neglect, it needs the expert's cooperation. If he/she is not willing to cooperate, he/she simply can say: "I don't know why it is like this or that. I simply do it".[14]

Another example regarding the amount of time necessary to rebuild an explicit knowledge model from tacit knowledge is given by researchers von Krogh, Ijicho and Nonaka (2000). They mention that it took a Japanese company seven years to develop a machine that removes the bones from chicken automatically, without any human intervention.

Figure F8: Identifying relationships between action and an expert's knowledge base.

[14] For a more detailed explanation see part C. of this report and the explanations for figure C7.



To recreate tacit knowledge in the explicit domain, the expert is observed and asked in detail about his/her actions. Often enough, the expert will not be able to explain why he/she is doing something in a certain way or why a machine may operate under certain conditions and not work in some other instances.[15] Such inability represents a major barrier to knowledge preservation and it causes the knowledge elicitation team a lot of trail and error testing to establish causal relationships between the expert's actions and the knowledge bases involved (see Figure F8).

The explicit knowledge developer creates a model of what he/she believes is a good representation of the expert's construction of reality. In order to accomplish this objective, the explicit model permanently has to be tested and verified to guarantee that it meets the expectations. Generally, in the beginning of such reconstruction work there is no guarantee that a viable explicit model may be developed or work.

However, when the recreation is done diligently and well, pay-off can be tremendous. Here is an example from the German machine tool-building industry. A company faced the following problem: when it assessed the costs of what a tool would cost to a car manufacturer, its cost estimates always exceeded the objective of plus/minus 5 percent deviation of the final price by a factor of 2 (i.e. 10 percent was the reality compared to 5 percent intended). This was a considerable threat to the firm's competitiveness. Because if the price communicated to the customer was too high, the order might go to

[15] A very good illustration to this can be found in professional sport disciplines where people may not replicate earlier performance levels in subsequent seasons. When asked why the perform in such an excellent form, they may say that they did good training, etc. Later on, when performance decreases or earlier levels cannot be reached again, they will say that they did excellent training sessions – but nevertheless success does not come.

a competitor. If the price was too low it might create financial problems for the firm (the average tool price was in the area of 500000 to 1000000 German Marks).

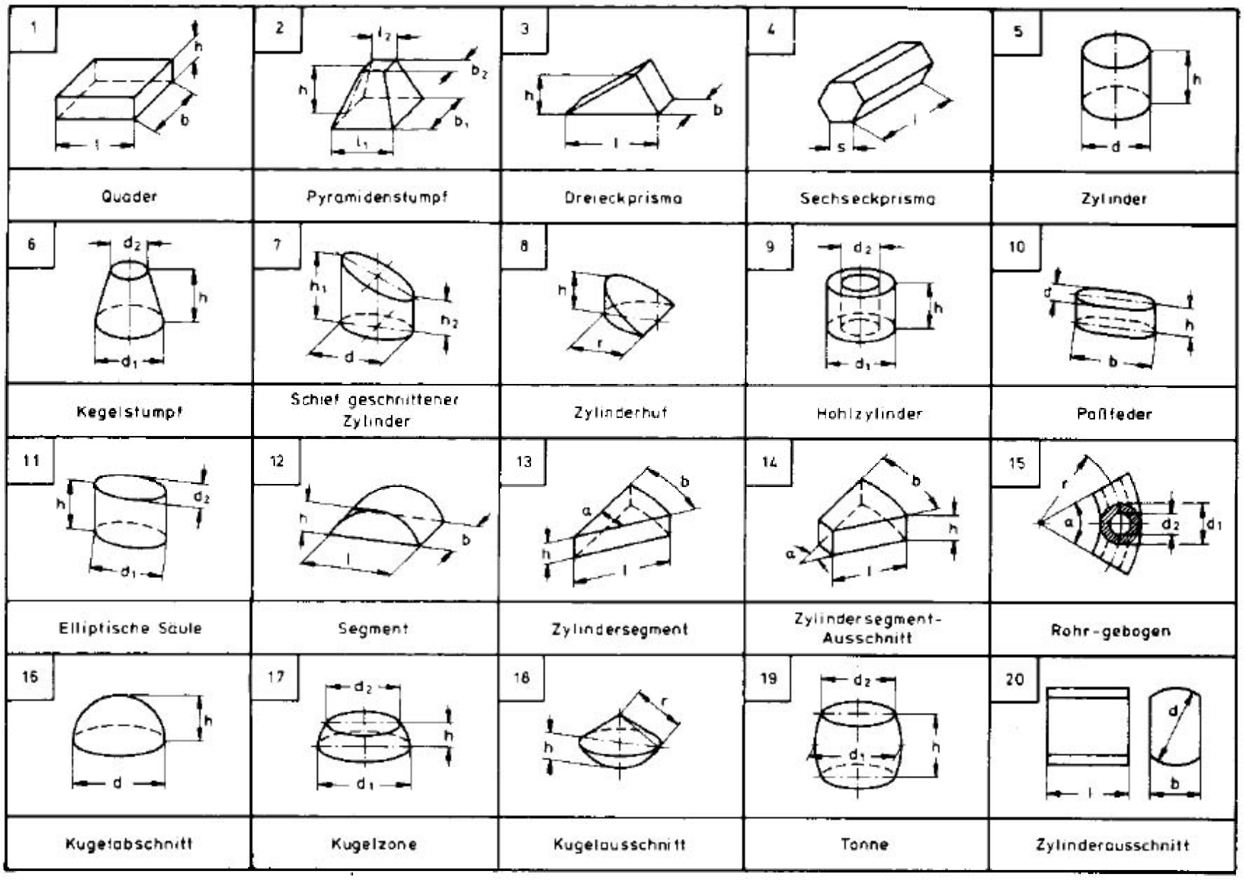
The price calculation was done through senior construction engineers with approximately 20 or more years of construction experience. Yet, this was all what management knew how price calculation was done. Thus a research project with a Berlin-based technical university was initiated.

The university's researcher started observing the senior engineers' activities when they were developing their assessment. He found out that they based their calculations on the similarity of sub-parts. The engineers compared the costs they assigned to earlier parts and then estimated how much a similar part probably would cost. Yet, often enough, such comparisons were not done as they had not done themselves similar parts in the past or they had forgotten where to find the information.

It was up to the researcher to develop a catalogue of parts (i.e. shapes) that could to be manufactured with the firm's machines (see figure F9). Based on dozen of basic parts then was developed a computer program to assess what would be the costs of a machine to manufacture a certain tool.

From the beginning the program performed very well – and better than the engineers' implicit models. Instead of variances in the area of 10 percent the program's variance was just 5 percent. Furthermore, after having the explicit model, improvements to the knowledge (model) itself became possible (or easier to do).

Figure F9: Catalogue of shapes of a machine-tool manufacturer.



Simulation

Simulation tools are powerful instruments to preserve knowledge and to allow a novice to acquire expertise independently of the knowledge's creator(s).

To create a simulation, explicit as well as tacit knowledge is needed. While it is easy to integrate explicit knowledge into the simulation model, integrating the tacit knowledge proves to be really difficult. Whenever human action is part of a process, simulation is difficult because of the human factor.

The benefit of a simulation becomes obvious in situations when an expert lacks the time to play the mentoring role.

The simulation allows the novice/successor to compress his/her learning curve because the knowledge that was integrated into the simulation serves as an "advance organizer" which – in the end – speeds up learning.

The benefits of simulation tools can be seen in the airline industry: training sessions in real airplanes have considerable cost disadvantages. Simulators allow airlines to train cockpit crews with much lower costs and minimal disadvantages to real-world training. However, to achieve such performance levels it took the providers of those simulators decades of work. And: while a 747 is the same to operate for German Lufthansa and French Air France, situations between NPPs might be far more heterogeneous and thus disadvantageous to the development of standardized simulators.

7.3. Assessment of the knowledge preservation strategies

The benefits and disadvantages of personalization strategies

Knowledge is in the heads of employees. The strength of the personalization strategy is the direct transfer of knowledge from one person (or group of person) to another person (group of persons). By direct interaction and close collaboration the recipient develops his/her own expertise. It is not a copy of the expert's knowledge but a new construction. The performance of the new construction might vary, although it primarily only should do so because of diverging cognitive abilities. A viable model (within the successor's head) is the result of the close cooperation and collaboration between the expert (mentor) and the successor. This close collaboration helps the expert to steer and influence the development of the successor's model and ensure its viability. From this point of view the *personalization strategy is the superior strategy to knowledge preservation*.

Substitution can be considered as the best way to preserve knowledge. With substitution a backup source for knowledge is created that can be tapped any time when it is necessary. If one source cannot be accessed, another can.

Tandems resemble the substitution activities in many aspects, although the backup is not available after a certain amount of time. Tandems are created intentionally when an employee's departure becomes a threat to an organization's operations. Depending on the successor's learning capabilities the time to transfer can be short or long.

Ideally, in both instances – for substitution as well as tandems (mentoring) – immediate feedback allows a novice/successor to change his/her mental model. Or, the knowledge source identifies mistakes in the recipient's knowledge base and enforces changes therein.

Communities of practice and **external experts** can be interesting complements or even substitutions to the first two measures mentioned here. Communities of practice create some costs (traveling, maintenance of the network), but they also have great benefits. In case of a (although not critical) problem an employee of a NPP may contact a colleague in another NPP and ask for help. Such help is normally granted – not on the basis of quid pro quo. In CoPs help is granted because the members of the community have joined the community in order to help each other. Helping others and being helped are *the* drivers of CoPs.

CoPs within an organization are also highly valuable. They represent a dynamic storage facility for knowledge. Even more, the communities often engage in developing new knowledge. Thus, CoPs are not only important to preserve but also to create knowledge.

In the situation of organization-spanning CoPs things look different. The support of such CoPs is– normally – not a firm's priority. CoP members still will help each other albeit this help will not enjoy priority among a member's activities. Therefore, in case of a problem, an employee may have to wait until his/her colleague can help. In some instances, this waiting time can be too long. Therefore, the use of organization-spanning CoPs is restricted to non time-critical NPP activities.

External experts have cost advantages (the backup does not cost as much compared to an employee) and the availability may be good dependent on the contract both parties agreed on. Further more, external experts don't have to be educated but are already experts in their field. They offer expert advice and quick solutions. Nevertheless, this solution also has its downside: the people dependence factor is rather high. As in all strategies related to personalization, humans are subject to illness or sudden death.

External experts also may lack the necessary context knowledge. Their activities may relate to the same knowledge base. Yet, as their knowledge normally is deployed in different contexts their capability for effective action within the nuclear industry may be limited.

Therefore, the elicitation of knowledge that is embrained in people and the creation of explicit knowledge models is per se an attractive option for NPPs. Such explicit knowledge models may be integrated into machines. In such instances, the knowledge is transferred to the supplier of the machines. This transfer also means that the preservation of knowledge is delegated to the supplier. Unfortunately, machines, and humans too, can fail.

Generally, the largest barrier to the personalization strategy are the associated costs. Substitutes mean that two people work for an organization when – at the extreme – only one is needed. Firms that operate NPPs and face competitive pressures might only see the costs without seeing the benefits.

The benefits and disadvantages of codification strategies

While the quality of the documents that are available in NPPs can be considered to be excellent, this might not be true for the documents that are created by knowledge preservation activities such as exit interview or knowledge elicitation. Those documents may share one major weakness: they are normally not designed with the customer in mind. Just pick up a VCR instruction manual and you hold the proof for this hypothesis in your own hands.

Documents are normally created with one's own needs in mind. Documents are normally not created for third parties as we do not know (much) about their skills. Thus, when a novice reads the document he/she may not be able to create the same ability of action compared to an expert. The novice will be able to read it, but he/she may not understand it. The knowledge cannot be applied.

Often enough, time pressure does not allow for documenting. Also, people often lack the motivation to work additional hours and document their activities. When documents are created during exit interviews and de-briefs, the interviewer must have considerable interviewing skills. At the same time, he/she always must compare what the experts explains to what a novice may or may not understand. He/she must build advance organizers into the resulting document in order to allow the novice to learn well and to allow him/her compress his/her learning curve.

This task is far from being easy as the concerning person may not be known at the time of the de-brief or exit interview. Thus, the quality of the document in the eyes of the potential reader depends very much from the image the interviewer had regarding the successor's skills.

Documenting, de-briefing and exit-interviews may need the help from external sources and thus come along with additional costs. Even more costs will arise when a NPP decides to develop an explicit knowledge model out of an expert's knowledge. Besides of the expert's willingness to contribute, there is no golden way to build explicit knowledge models. Developing an explicit knowledge model is time-consuming and cost intensive. When such a model is integrated into a simulation tool, costs are increasing. However, such tools provide a great independence from the knowledge source and provide ample opportunities to improve the knowledge itself.

One cannot say which method is generally the best. It always depends on the situation and the context which method should be applied. And even when a certain method is superior it might not be available (e.g. a new hire is not vailable before the retirement of the expert).

Only after the analysis of the situation an ideal strategy can be developed and exercised.

8. Terminology[16]

The following definitions of terms apply specifically to the field of Knowledge Management. It should be noted that identical terms applied to, or used in, other fields may have somewhat different definitions.

Knowledge Management itself is defined as an integrated, systematic approach to identifying, managing and sharing an organisation's knowledge, and enabling persons to create new knowledge collectively and thereby help achieve the objectives of that organisation.

Adaptive learning

The use of knowledge to solve specific problems based on existing assumptions, and often based on what has been successful in the past. Also termed Single-loop learning.

Comment: In contrast, double-loop learning goes a step further and questions existing assumptions in order to create new insights (see double-loop learning). For example, take the problem 'how to prevent earthquakes from killing people?'. The single-loop answer would be to learn how earthquakes happen and try to predict them in order to be prepared. The double-loop answer would question the notion of 'earthquake' and might conclude that earthquakes do not kill people, falling buildings do.

After-action review

A process that involves conducting a structured and facilitated discussion after a task or project has been completed to review what should have happened; what actually happened; and, where differences exist, why it happened. Also termed Post-job briefing.

Comment: After action review allows participants to learn how to sustain strengths and improve on weaknesses in subsequent tasks or projects. It is used to help teams to learn quickly from their successes and failures and share their learning with other teams.

After event review

A process that involves consideration of the what, how and why of unplanned events.

Comment: After event review includes analysis in sufficient depth to determine contributing factors (including behavioural, organisational and physical conditions); precipitating actions; consequences; probable causes; lessons learned; and corrective actions to minimise recurrence. In the nuclear industry, organisations focus attention on such problem-solving endeavours, through systematic and systemic analyses, to determine the most probable root causes of such events in order to correct problematic conditions and to prevent recurrence of similar events. (see Root cause analysis).

[16] Appreciation is expressed to all individuals who contributed to the development of this document, especially to C.R. Chapman (UK), L. B. Durham (USA), and T.J. Mazour (IAEA). Particularly thanks are due to C.R. Chapman who has compiled and prepared the entire version.

Articulation
The process of making tacit knowledge explicit. Also termed Externalisation. See also Internalisation.

Artificial intelligence

1. The ability of a computer or other machine to perform those activities that are normally thought to require intelligence.

2. The branch of computer science concerned with the development of machines having this ability.

Asset management

An approach to responsible management of an enterprise that considers, in a balanced fashion, the entirety of its resources: personnel, facilities, equipment, fiscal investment; and intangible assets such as goodwill, intellectual property and corporate knowledge.

See Intangible assets, and also Intellectual assets, and Knowledge assets.

Comment: An organisation’s assets can be physical or intellectual or a mixture of these.

Attrition
A decrease in the number of employees in an organisation due to retirements, other terminations, or transfers to other organisations. In the nuclear industry attrition due to retirement is a particularly important issue because plants typically have stable workforces, all or most of whom joined during the commissioning phase, and thus they often have quite similar retirement dates.

Balanced scorecard

A business model used as a tool to measure organisational performance against both short and long-term goals.

Comment: The ‘balanced scorecard’ is designed to focus attention on the factors that most help business strategists and so, alongside financial measures, offers means of measuring internal processes and employee learning. Some organisations in the nuclear industry use the ‘balanced scorecard’ model in setting and measuring knowledge management strategies.

Benchmarking

The practice of comparing features and performance of an organisation, department or function against those of other organisations and standards.

Comment: The following axioms should be considered in benchmarking:

- What works well for a given organisation in one situation may not work well in another organisation under different circumstances.

- There are lessons to be learned from undesirable situations as well as from best practices – things that have been proven to work well and produce good results.

- Examining the practices of organisations with fundamentally different aims can produce surprisingly useful insight about another organisation.

Capacity building

The process of enhancing an organisation's ability to achieve its goals.

Champion

A person who proactively promotes something with the aim of persuading others of its benefits. In the nuclear industry a champion for organizational change is often a senior line manager who regularly monitors the plans and progress in implementing change, and helps to overcome barriers to change.

Chief Information Officer (CIO)

A senior position with strategic responsibility for information management and information technology.

Chief Knowledge Officer (CKO)

A senior position with strategic responsibility for promoting and implementing knowledge management.

Coaching

A one-to-one relationship that aims to bring about individual learning and performance improvement, usually focusing on achieving predefined objectives within a specified time period. The role of the coach is to create a supportive environment in which to challenge and develop the critical thinking skills, ideas and behaviours of the person being coached, so that person might reach their full potential. In the nuclear industry experienced staff are often assigned as coaches to help new employees to achieve their structured on job training programmes. See also Mentoring and Reverse Mentoring.

Codification

The process of converting people's knowledge into a form to enable it to be communicated independently of those people. The most common method is writing things down and incorporating them into documents and databases. Other methods include pictures, and sound and video recordings. In the nuclear industry codification has been particularly important in ensuring that the design basis for the plants safe operation is effectively maintained. See also Knowledge harvesting.

Collaboration

A generic term to describe teamwork or a group effort. In knowledge management it is often used more specifically to describe close working relationships involving the sharing of knowledge. An example of collaboration in the nuclear industry is a cross-functional team.

Communities of practice

Networks of people who work on similar processes or in similar disciplines, and who come together to develop and share their knowledge in that field for the benefit of both themselves and their organisation(s). Communities of practice may be created formally or informally, and they can interact online or in person. Sometimes referred to as

Communities of interest in the less formal context. An example in the nuclear industry is the Nuclear Energy Institute's Community of Practice.

Concept maps

Concept maps are tools for organizing and representing knowledge. They include concepts, usually enclosed in circles or boxes of some type, and relationships between concepts or propositions, indicated by a connecting line between two concepts.

Configuration management

The process of identifying and documenting the characteristics of a facility's structures, systems and components (including computer systems and software), and of ensuring that changes to these characteristics are properly developed, assessed, approved, issued, implemented, verified, recorded and incorporated into the facility's documentation.

Comment: The IAEA report on Configuration management in nuclear power plants (IAEA-TECDOC-1335, January 2003) presents a basic approach to Configuration management, taking into consideration experience gained from organizations and utilities which have successfully implemented partial or full Configuration management programmes and from discussions at meetings organized on the subject.

Content management

A means of ensuring that computer-based information, such as the content of a website or a database, is relevant, up-to-date, accurate, easily accessible, or well organised, so that quality information can be delivered to the user.

Comment: Configuration management, as used in the nuclear industry, is an effective tool for the maintenance of content management.

Corporate memory

The knowledge and understanding embedded in an organisation's people, processes and products or services, together with its traditions and values. Corporate memory can either assist or inhibit the organisation's progress. Also termed Organisational memory.

Comment: Corporate memory becomes a critical concern when there is sufficient migration from an organisation as to cause a knowledge deficit. This phenomenon can happen due to factors such as planned reductions in the workforce, accidents, illness, retirements, or – most commonly – personnel leaving due to dissatisfaction with immediate supervision. In situations such as those mentioned, the tremendous financial investment in an organisation's personnel and their tacit knowledge becomes quite apparent. In the nuclear industry corporate memory is particularly important in ensuring that the design basis for the NPP safe operation is effectively maintained.

Customer Relationship Management (CRM)

A business strategy based on selecting and proactively managing the most valuable customer relationships. A customer-focused philosophy is necessary to support effective marketing, sales and customer service processes.

Data

Sets of facts, concepts or statistics that can be analyzed to produce information.

Database

A collection of information organised in such a way that a computer program can quickly select desired pieces of data. Relational databases are organised by fields, records, and tables. A field is a single piece of information; a record is one complete set of fields; and a table is a collection of records. Storing content in fields rather than static pages makes that content appropriate for dynamic delivery.

The International Nuclear Information System (INIS), maintained by the International Atomic Energy Agency (IAEA), is the world's leading information system on the peaceful uses of nuclear science and technology. This database indexes scientific literature published worldwide on the peaceful applications of nuclear science and technology focusing on technical data, references, and bibliographies from the world's biggest digital nuclear reference centres in fields of nuclear science and technology. Legal and social aspects associated with nuclear energy are included, as well as the economic and environmental aspects of all non-nuclear energy sources.

Data mining

A technique for analysing data in databases and making new connections between the data in order to reveal trends and patterns.

Demographics

Social statistics that are often useful in workforce composition and planning.

Comment: Factors such as age, gender, race, ethnicity, educational level, and professional qualification can be most helpful in achieving organisational goals and objectives. For example, developing a demograpic profile of an organisation can help with succession planning and recruiting. In the context of Knowledge Management, attrition is the most relevant demographic (see Attrition).

Document

A record of an event or knowledge, taken so that the information will not be lost. Documents are usually written, but they can also be made up of images or sound. Documents can be put into electronic or digital form and stored in a computer.

Document management

Systems and processes for managing documents including the creation, editing, production, storage, indexing and disposal of documents. This often refers to electronic documents and uses specific document management software.

Comment: The IAEA report on Information Technology Impact on Nuclear Power Plant documentation (IAEA-TECDOC-1284, April 2002) addresses all aspects of documentation associated with various life-cycle phases of NPPs and the information technology (IT) that are relevant to the documentation process. It also provides a guide for planning, designing, and executing an IT documentation project. Examples are given to demonstrate successful implementations at plants. It also discusses the issues related to the application of IT at NPPs and the trends for applications of the IT at NPPs as well as the technology itself.

Double-loop learning

In contrast to single-loop learning (see single-loop learning), which involves using knowledge to solve specific problems based on existing assumptions and often based on what has worked in the past, double-loop learning goes a step further and questions existing assumptions in order to create new insights.

Comment: Consider the problem “how do we prevent earthquakes from killing people?”. The single-loop answer would be to learn how earthquakes happen and try to predict them in order to be prepared. The double-loop answer would question our notion of “earthquake” and might conclude that earthquakes do not kill people, falling buildings do. Also termed Generative learning.

E-Business

An abbreviation of electronic business. The use of electronic information systems (especially internet technologies) in business processes.

E-Learning

An abbreviation of electronic learning. The use of electronic information systems (especially internet technologies) to deliver or receive learning and training. A common application of E-learning in the nuclear industry is general employee refresher training. Due to the large number of participants in this training, the relatively high cost of E-learning can be justified, and the flexibility of E-learning is well suited to allowing participants to complete the training when they have the time available. Also, a “test-out” feature can allow participants who already know the material to complete a pre-test, and if successful to avoid training time on topics which they already know.

Events

Activities, occurrences, or incidents – planned or unplanned – that have significance to society, organisations or individuals.

Comment: In nuclear technology fields, “events” are typically both unplanned and undesirable. Some regulatory systems have categories for events based on their levels of severity, i.e. their potential for harmful results.

Exit interview

A survey that is conducted with an employee is about to leave an organisation.

Comment: The information from each exit interview is used to provide feedback on why employees are leaving, what they liked about their employment and what areas of the organisation need improvement. Exit interviews are used as part of knowledge harvesting (see knowledge harvesting) to glean knowledge from the departing employee so that it is retained in house.

Expert system

A data processing system that provides for expertly solving problems in a given field or application area by drawing inferences with the aid of a knowledge base developed from human expertise. A branch of artificial intelligence (see artificial intelligence).

Expertise directory

A directory in the form of a database that includes details of people's skills, knowledge, experience and expertise so that users can search for people with specific know-how. Also termed Experts directory and Skills directory. See also White pages.

Experts directory

An alternative term for Expertise directory.

Explicit knowledge

Knowledge that can be easily expressed in documents. Examples include NPP documentation and databases such as a website, an operational manual, records or a report of research findings. See also Tacit knowledge and Implicit knowledge.

Externalisation

An alternative term for Articulation (see Articulation). See also Internalisation.

Extranet

A computer network that links an organisation with other specific organisations or persons. Extranets are accessible only to specified organisations or persons and are protected by passwords. See also Intranet

Generative learning

An alternative term for Double-loop learning.

Good practice

See: Best practice.

Groupware

Computer software applications that are linked by networks, and so allow people to work together and share electronic communications and documents.

Human assets

The knowledge, skills and competences of the people in an organisation. Human assets are a component of intellectual assets (see intellectual assets).

Implicit knowledge

The knowledge or know-how that people carry in their heads. Compared with explicit knowledge (see explicit knowledge), implicit knowledge is more difficult to articulate or write down and so it tends to be shared between people through discussion, stories and personal interactions. It includes skills, experiences, insight, intuition and judgement. Also termed Tacit knowledge.

Comment: Some authors draw a distinction between tacit and implicit knowledge, defining tacit knowledge as that which cannot be written down, and implicit knowledge as that which can be written down but has not been written down yet. In this context, explicit knowledge is defined as that which has already been written down.

Information

Data that has been organised within a context and translated into a form that has structure and meaning.

Information audit

A method of reviewing and mapping information within an organisation. An information audit examines what information is needed, what information there currently is, where it is, in what forms, how it flows around the organisation, where there are gaps and where there is duplication, how much it is costing, what its value is, how it is used etc. See also Knowledge audit.

Information management

The management of an organisation's information resources with the aim of improving the performance of the organisation. Information management underpins knowledge management, as knowledge is derived from information.

Information overload

A state where persons have so much information that they are no longer able to effectively process and make use of it.

Information technology (IT)

The elements of computing, including software, servers, networks and desktop computing, which enable digital information to be created, stored, used and shared.

Institutional knowledge

The collective knowledge of all the employees working in an organisation or institution.

Intangible assets

The non-physical assets or resources of an organisation. Examples in the nuclear industry include the skills and knowledge of plant personnel, and the reputation of the organisation (with the regulatory body and the public) for safe and effective plant operation

Integrated staffing plan

A plan that is designed to ensure that an organisation has the right skills at the right time and at the right cost. The plan is a standardized and consistent methodology for overall human resources planning, driven by strategic and business objectives.

Intellectual assets

An alternative term for knowledge assets.

Intellectual assets management

A part of knowledge management that focuses on issues relating to intellectual property such as organising and exploiting patents, copyrights, trademarks and other intellectual property rights.

Intellectual capital

The value, or potential value, of an organisation's knowledge assets. An attempt by organisations to place a financial value on their knowledge. See Knowledge assets.

Intellectual property

Explicit knowledge assets that are protected by law. 'Intellectual property' includes items such as patents, trademarks, copyrights, licences etc.

Internalisation

The process of absorbing explicit knowledge and making it tacit. See also Externalisation.

Intranet

A computer network that functions similarly to the internet, but the information and web pages are located on computers within an organisation rather than being accessible to the general public. See also Extranet.

Know-how

Skill or competence derived from knowledge and experience.

Knowledge

The acquiring, understanding and interpreting of information.

Comment: Knowledge is distinct from information as knowledge is information that has a purpose or use. Data leads to information and information leads to knowledge. Knowledge confers a capacity for effective action.

Knowledge may be applied to such purposes as problem solving and learning, forming judgements and opinions; decision making, forecasting and strategic planning; generating feasible options for action and taking actions to achieve desired results. Knowledge also protects intellectual assets from decay, augments intelligence and provides increased flexibility.

Knowledge is often used to refer to a body of facts and principles accumulated by humankind over the course of time. Explicit knowledge is contained in documents, drawings, calculations, designs, databases, procedures and manuals. Tacit knowledge is held in a person's mind and has typically not been captured or transferred in any form (if it were, it would then become explicit knowledge).

See also Explicit knowledge, Implicit knowledge and Tacit knowledge.

Knowledge assets

Those parts of an organisation's intangible assets (q.v.) that relate specifically to knowledge, such as know-how (q.v.), best practices (q.v.), and intellectual property (q.v.). Knowledge assets are often divided into human (people, teams, networks and communities), structural (the codified knowledge that can be found in processes and procedures) and technological (the technologies that support knowledge sharing such as databases and intranets). Also termed Intellectual assets.

Comment: By understanding the knowledge assets an organisation possesses, the organisation can improve its ability to use them to best effect and also identify any gaps that may exist.

Knowledge audit

A method of reviewing and mapping knowledge in an organisation including an analysis of its knowledge needs, resources, flows, gaps, users and uses. A knowledge audit generally includes aspects of an information audit (see information audit) but is broader than an information audit.

Knowledge base

The fundamental body of knowledge (see knowledge) available to an organisation, including the knowledge in people's heads, supported by the organisation's collections of information (see information) and data (see data). An organisation may also build subject-specific knowledge bases to collate information on key topics or processes. 'Knowledge base' is also sometimes used to describe a database of information. The nuclear industry has variety of knowledge bases; some are industry wide, such as the IAEA's PRIS and INIS. NPP operating organisations knowledge bases include the plant procedure systems, system description documents and technical manuals.

Knowledge broker

A person who facilitates the creation, sharing and use of knowledge within an organisation. Many organisations have created knowledge broker roles such as a 'Knowledge Co-ordinator'. 'Knowledge broker' is also sometimes used to describe a company or individual that operates commercially as a knowledge trader or provides knowledge-related services.

Knowledge center

A place where knowledge is gathered and stored and can be accessed and used. It may be a physical place such as a library, a virtual place (a knowledge portal), such as an interactive website or online discussion board, or a place where people gather such as a café, an informal meeting room or a discussion area created to encourage knowledge sharing.

Knowledge economy

An economy in which knowledge plays a predominant part in the creation of wealth.

Knowledge flows

The ways in which knowledge moves within, and into and out of, an organisation.

Knowledge harvesting

A set of methods for making tacit knowledge (see tacit knowledge) more explicit - incorporating people's knowledge into documents, to enable it to be more easily shared with others. See also Codification.

Knowledge loss risk assessment

A process used to determine the potential business impact of the loss of critical knowledge from an organization.

Comment: This process is a part of organisation's overall strategy to address the challenges created by an ageing workforce. The process is designed to:

- Identify expert incumbents who possess critical knowledge and skills
- Conduct a "Risk Assessment" based on two factors: time until retirement and position criticality.
- Determine the most appropriate method(s) for addressing potential knowledge loss through attrition.
- Establish Knowledge Retention Plans that meet continuously changing business needs.
- Provide a process to review results and ensure Knowledge Retention Plans are monitored and evaluated.

See Knowledge retention plan.

Knowledge management

The integrated, systematic approach to identifying, managing and sharing an organisation's knowledge, and enabling persons to create new knowledge collectively and thereby help achieve the objectives of that organisation.

Knowledge management solution

A solution to a knowledge management problem, or the use of knowledge management techniques to solve an organisational problem. Examples of 'knowledge management solutions' include upgrades of plant procedure systems to provide additional detail, mentoring assignments for employees soon to retire, and more structured on the job training programmes.

Knowledge management strategy

A detailed plan outlining how an organisation intends to implement knowledge management principles and practices in order to achieve organisational objectives.

Comment: There are many strategies used to preserve knowledge. Primarily, the activities to be deployed largely depend on the nature of knowledge: tacit knowledge requires greater efforts to preserve knowledge than explicit knowledge. While tacit knowledge can be preserved only by transferring it to successors or simply other people (so-called personalisation strategy), explicit knowledge benefits from the possibility of codification (articulation) and its storage with the help of advanced information and communication technologies. Preserving tacit knowledge is equal to transferring tacit knowledge to other employees or to engage in a knowledge transformation process that transforms tacit knowledge to explicit knowledge. Such endeavours are highly time-consuming.

Generally, two categories of knowledge preservation strategies (activities) can be discerned: personalisation strategies (knowledge transfer) and codification strategies (knowledge articulation/elicitation).

Knowledge mapping

A process to determine where knowledge assets (see knowledge assets) are in an organisation, and how knowledge flows (see knowledge flows) operate within the organisation. Evaluating relationships between holders of knowledge will then illustrate the sources, flows, limitations, and losses of knowledge that can be expected to occur.

Knowledge officer

A role with responsibility for implementing knowledge management principles and practices. See also Chief knowledge officer.

Knowledge repository

A place to store and from which to retrieve explicit knowledge. A low-technology knowledge repository could be a set of file folders. A high-technology knowledge repository might be based on a database platform.

Knowledge retention plan

A plan that identifies the critical knowledge and positions in an organisation, and methods to be used for addressing potential knowledge loss through attrition, and the process that will ensure that the plan is continually updated to meet changing business needs.

Knowledge transfer

The transfer of knowledge in a broad array of settings: between individuals, groups of individuals, communities, organizations, industries, or even nations.

Comment: Several “levels of transfer” can be distinguished, depending on complexity. At level I, the objects of transfer are data and materials (materials, components, intermediate and end products, etc.). Such knowledge transfer will not enable the recipient to recreate the sender’s knowledge. At level II the sender transfers documentation and blueprints and the necessary information to manufacture products based on documentation and blueprints. Documentation and blueprints correspond to the explicit knowledge of the original technology developer. At level III the recipient is able to reproduce the knowledge and change it, adapting it to different conditions. Such transfers have to be accompanied by elements of level I and II transfers in order to make the recipient fully understand the sender’s knowledge.

Knowledge worker

An employee whose role relies on an ability to find and use knowledge.

Learning

See Adaptive learning, E-Learning, Double-loop learning, Generative learning, Learning organisation, Organisational learning, and Single-loop learning.

Learning organization

An organisation that views its future success as being based on continuous learning and adaptive behaviour. The organisation, therefore, becomes skilled at creating, acquiring, interpreting and retaining knowledge and then modifying its behaviour to reflect new knowledge and insights.

Lessons learned

Concise descriptions of knowledge derived from experiences that can be communicated through mechanisms such as storytelling (see storytelling), debriefing etc, or summarised in databases. These lessons often reflect on "what was done right," "what should be done differently," and "how to improve the process and product to be more effective in the future." In the nuclear industry operating experience feedback is an example of an applied lessons learned programme.

Leverage

The realisation of the inherent value of an asset - physical or knowledge-based - beyond what is currently being realised. In short, to get more value out of it.

Mentoring

A one-to-one teaching/learning relationship in which a senior member of an organisation is assigned to support the development of a newer or more junior member by sharing knowledge, experience and wisdom. See also Coaching.

Comment: While the strength of mentoring lies in transferring the mentor's specific knowledge and wisdom, in coaching it lies in the coach's ability to facilitate and develop the other's own personal qualities. In the nuclear industry, mentoring is often used to prepare candidates for senior management positions, with an incumbent manager being the mentor. Coaching in the nuclear industry is often used for structured OJT programmes for new technicians, operators and engineers.

Multi-skill assistance

A process in which an individual or team arranges a meeting or a workshop in order to make use of the knowledge and experience of others before embarking on a project or activity. In the nuclear industry some organisations have established multi-skilled teams for maintenance work, where each team has the collective skills needed to complete their assigned work. Often team members provide cross-training for other team members on simpler tasks in their discipline in order that team members can individually be assigned to a broader range of tasks. Also termed Peer Assistance.

Organisational culture

A mixture of an organisation's traditions, values, attitudes and behaviours. In short, 'the way things are done around here'. Different organisations can have very different cultures.

Comment: In knowledge management, an organisation's culture is extremely important - if it is not based on qualities such as trust and openness, then knowledge management initiatives are unlikely to succeed. In the nuclear industry some organizations use organizational culture surveys, which among other things, helps managers to know the extent to which the organizational climate supports sharing of knowledge.

Organisational learning

The ability of an organisation to gain knowledge from experience through experimentation, observation, analysis and a willingness to examine both successes and failures, and to then use that knowledge to do things differently.

Comment: While organisational learning cannot take place without individual learning, individual learning does not necessarily produce organisational learning. Organisational learning occurs when an organisation becomes collectively more knowledgeable and skillful in pursuing a set of goals.

Organisational memory

An alternative term for Corporate memory (see Corporate memory).

Organisational silo

An individual group within an organisation, such as a department or unit. ‘Silo’ is often used to suggest that such groups tend to be inward-looking and do not take into account what other similar groups are doing or how their work affects other such groups.

Peer assistance

An alternative term for Multi-skill assistance (see Multi-skill assistance).

Portal

A special web page that organises access to all of the online resources relating to a topic, similar to providing a “one-stop shop”.

Position disposition

The determination of whether or not a position will be refilled when vacated.

Post-job briefing

An alternative term for After-action review (see After-action review).

Pre-job briefing

A process that involves conducting a structured and facilitated discussion before a task or project is performed to explain what should happen. See also After-action review.

Records management

Processes relating to the generation, receipt, processing, storage, retrieval, distribution, usage and retirement of an organisation's records.

Comment: A means of helping an organisation to make sure it is creating and maintaining an adequate documentary record of its functions, policies, decisions, procedures, and essential transactions, whether in paper, film, electronic record, or some other medium. Records management thus helps the organisation to decide which records to keep and which to destroy and how best to organise them all.

Review

See After action review, After event review and Periodic review.

Search engine

An item of software that searches for information.

Silo

See: Organisational silo.

Single-loop learning

An alternative term for Adaptive learning. See also double-loop learning.

Skills directory

See: Expertise directory

Socialisation

The process of sharing tacit knowledge by bringing people together to discuss topics, share experiences or work together.

Comment: For example, the use of storytelling in organisations is a way of sharing knowledge and aiding learning. Stories can be very powerful communication tools, and may be used to describe complicated issues, explain events, communicate lessons learned, or bring about cultural change. Practices like this create tacit knowledge and aid acculturation of new employees into their work environments. Socialisation within an organization aids towards the transfer of knowledge.

Storytelling

See: Socialisation.

Succession planning

A methodology for identifying and developing employees to ensure that key organizational positions can be filled with qualified internal candidates, in advance of actual need, and to assist in managing diversity and workforce planning.

Comment: When necessary, candidates may be recruited externally. In the nuclear industry succession planning is often used for management and senior technical positions.

Tacit knowledge

See Implicit knowledge.

Taxonomy

A hierarchical structure in which a body of information or knowledge is categorised, allowing an understanding of how that body of knowledge can be broken down into parts, and how its various parts relate to each other. Taxonomies are used to organise information in systems, thereby helping users to find it.

Thesaurus

A hierarchical arrangement of related words and phrases often displayed in systematised lists of synonyms.

Undocumented knowledge

Knowledge in an organisation that has not been documented in such a way that it is accessible to those who may need it.

Comment: Undocumented knowledge can be tacit knowledge which may be very difficult to elicit, such as clues that an experienced field operator uses to anticipate problems at an NPP, or knowledge that can easily be externalised, such as an engineer's informal calculation of the basis for the minimum required feed water flow that has never been included in the appropriate plant system description document.

Virtual

Something that exists or is brought together via electronic networks, rather than existing in a single physical place. See also Portal and Virtual team.

Virtual team

A team whose members are not located together but who utilise electronic networks for communication, collaboration and work processes.

White pages

A structured directory, usually in electronic form, of people within an organisation. It often forms the basis for an expertise directory (q.v.).

Work force planning

A process that outlines expected retirements and vacancies as well as the required staffing levels needed to support future business strategies.

Comment: This information becomes a part of the staffing plan in an organisation's business plan. It includes attrition data, planned retirements, vacant positions, development plans, succession plans, and current work force requirements.

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10. Appendix: The Process of Transferring Knowledge

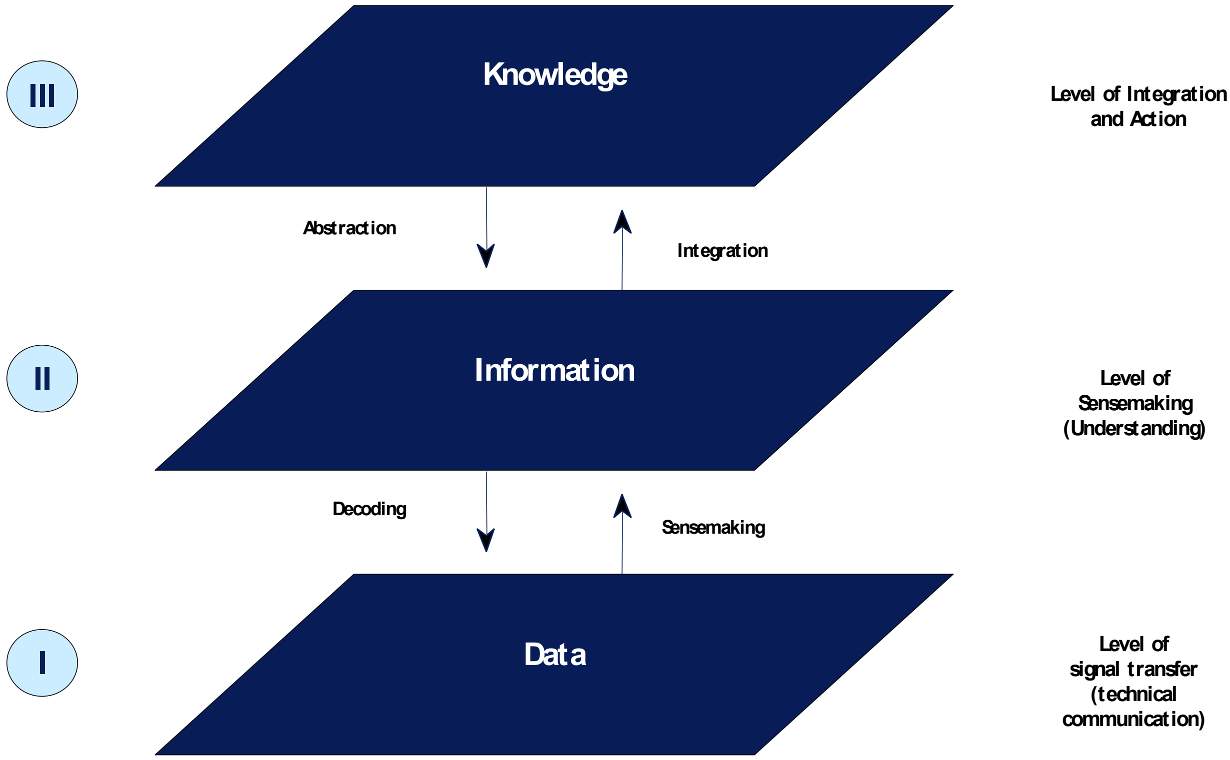
Transfers of technological and other knowledge are far from being new. Over the course of thousands of years mankind identified the transfer of people as the most effective way to transfer knowledge, as is highlighted by a leading manager from ABB: “You transfer technology (knowledge) with a pair of shoes. If you want to transfer the technology, transfer the person. That's absolutely far and away the best way to do it”.

Transferring Data, Information, and Knowledge

Knowledge transfer can happen in a broad array of settings: among individuals, groups of individuals, communities, organizations, industries, or even nations. In relation to the complexity several “levels of transfer” can be distinguished (see figure App1). On *level I*, the object of transfer is data and materials (materials, components, intermediate and end products, etc.). This kind of transfer will not enable the recipient to recreate the sender’s knowledge. On step further goes the transfer on *level II*. Here, the sender transfers documentation and blueprints and the necessary information to manufacture products based on the documentation and blueprints. Documentation and blueprints correspond to the original technology developer’s *explicit knowledge.*

Transfer on level III allows the recipient to reproduce the knowledge and change it, adapting it to different conditions. **Such transfers have to be accompanied by elements of level I and II transfers in order to make the recipient fully understand the sender’s knowledge.**

Figure App1: Data, Information and Knowledge.



Basic Elements of Knowledge Transfer

Each transfer of knowledge at least comprises three elements: a sender, an object, and a recipient. Despite a considerable amount of research into the transfer of knowledge and technology, the process of transferring knowledge has largely remained a black box.

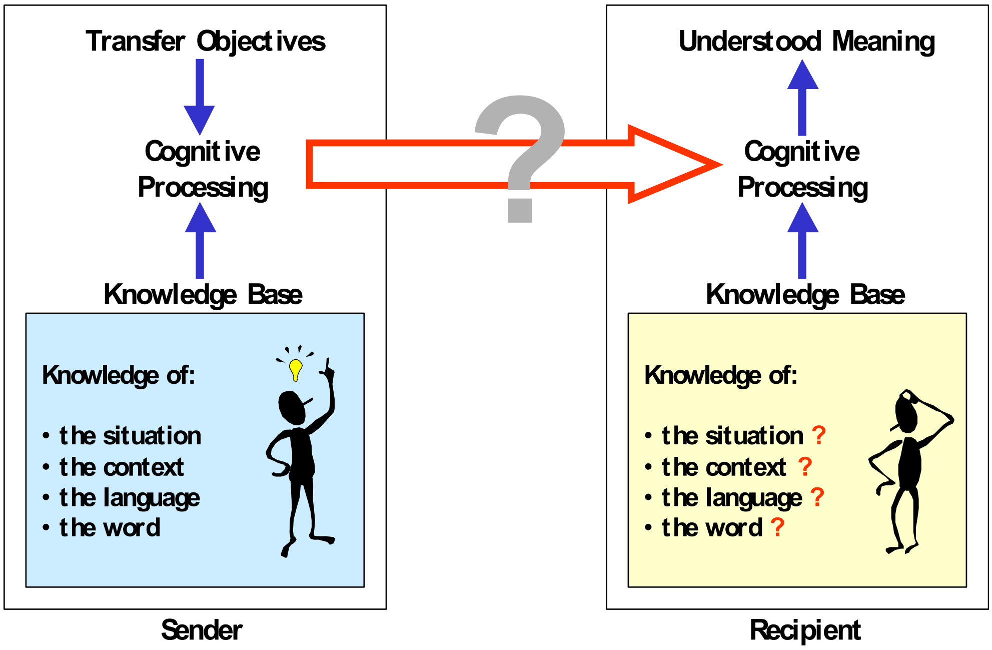
Every knowledge originates with people. This people's knowledge, dubbed expertise, is the object of manifold research (cognition psychology, cognitive science, information processing) and has gained considerable attention in the last few years. In the past, expertise was to be considered given to an individual; this view on expertise has changed recently as expertise now is mainly considered to be acquired. Experts acquire their skills and expertise within a specific context which allows them to perform quicker and better than non-experts within a certain domain. The process of acquiring expertise is situated in a context of multiple authentic activities and is a long-lasting process of learning, knowledge acquisition, knowledge refinement, development of problem solving skills.

The importance of the context within which expertise builds up becomes evident when experts are challenged to elicit their knowledge, e.g. when they are challenged to put their knowledge into an expert system. The problems arising from eliciting the knowledge bases which are the basis of the experts' superior performance highlight the importance of the implicit knowledge on which experts rely to solve problems. Such *tacit knowledge* is key to expertise.

Object of the Transfer: Knowledge

The ability to act is the main difference between information and knowledge. Knowledge as intangible construction makes clear that no such thing as knowledge transfer in the sense of the word does exist. As knowledge is a subjective and personal construction, any kind of transfer of such construction is impossible. Figure App2 tries to illustrate this point: Without any knowledge about the situation and the context which was constituent to build up one's expertise, the recipient never will be able to achieve the outcome of the transfer intended. Knowledge transfer is not easy to achieve as one cannot tie the technology up in a package, hand it over to the recipient who would then open the package and say wonderful.

Figure App2: Multi-Dimensional Challenge of Knowledge Transfer.

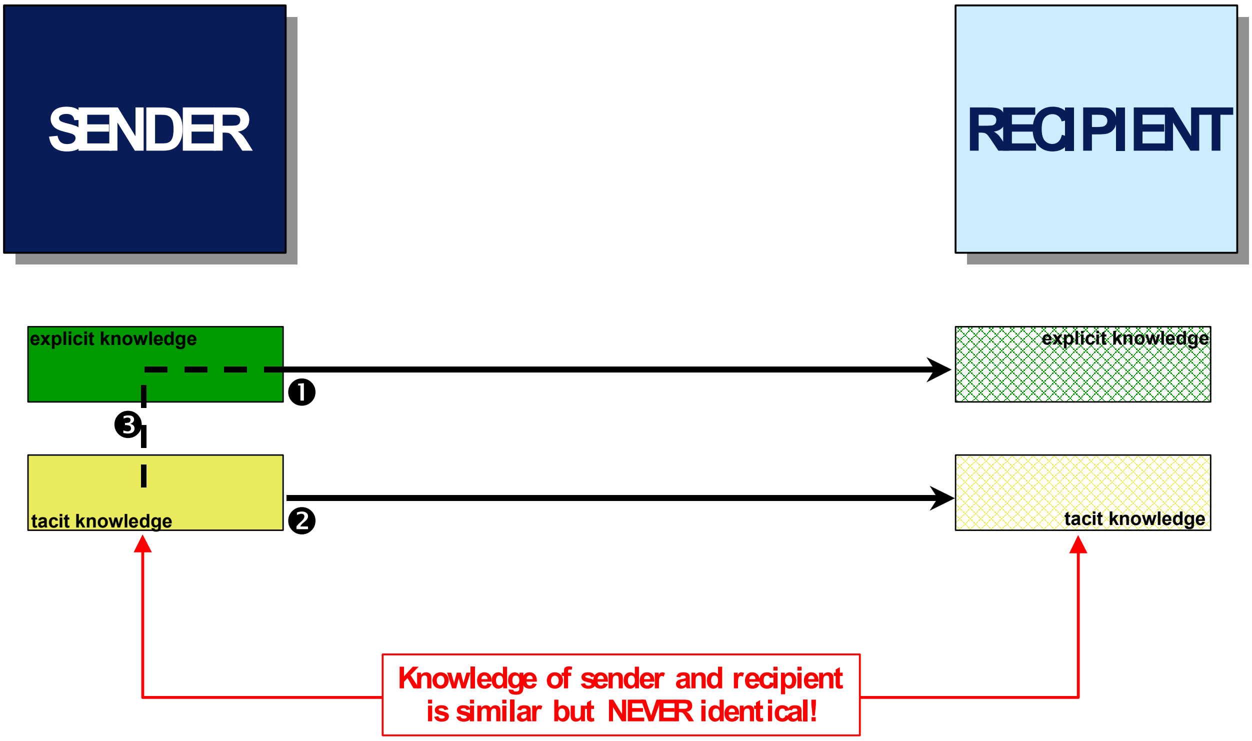


Whatever is sent, it has to allow the recipient to develop his or her those cognitive structures that will enable him/her to achieve the objectives intended: knowledge does not exist outside of individuals, it is what people construct and agree upon. As the situation and the context of the re-construction of knowledge [by the recipient] will be different from the creator's one, both will end up with *different knowledge*.
While it is easy to postulate to achieve a re-construction of knowledge by the recipient, knowledge transfer is far more difficult to achieve than thought.

Drafting the Technology Transfer Process
There is a variety of means to transfer knowledge. However, tacit and explicit knowledge demand different transfer strategies. While explicit knowledge may be transferred by the way of document transfer, such a transfer is not applicable to tacit knowledge.

While there are three basic transfer processes (see Figure App3), the transfer of knowledge may be limited to strategies ❶ and ❷.

Figure App3: Three Basic Processes of Knowledge Transfer.[17]

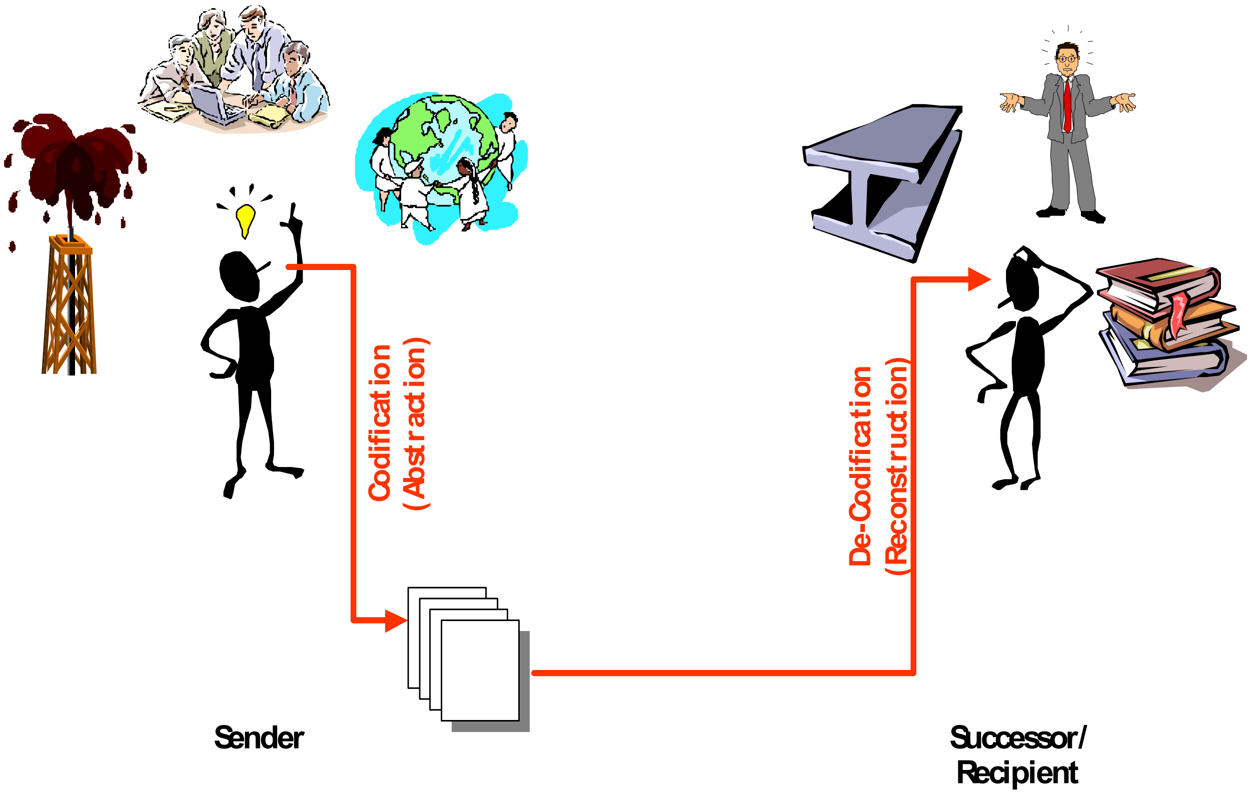


Nonaka (1991) notes that tacit knowledge can be shared by observation and imitation and thus is transferable. Such transfer has a long tradition in craftsmanship. However, the master's cognitive processes remain hidden to the apprentice. In technology transfer, those cognitive processes are key and the question arises how knowledge is transferred in such a case (process ❷).

Although document transfer may appear simple and straightforward at first, document transfer's ease may turn out to be wrong. Although explicit knowledge may be less situation and context specific than tacit knowledge, its language and symbols are often idiosyncratic and far from easy to understand for people not familiar with the original situation/context. Thus, any document is witness to the specific situation and context of its creation (see figure App4). Further more, documents often are only created with the idea of supporting re-creation of the capacity to act for the knowledge's creator, leaving potential other "users" in the dust.

[17] While the same basic colors are assigned to the explicit and tacit knowledge, the recipient's knowledge has is given a pattern to indicate that it is not the same knowledge.

Figure App4: Diverging Contexts Among Sender and Recipient.



As was noted above the transfer of tacit knowledge has been practiced for centuries (e.g. in craftsmanship). In *apprenticeship situations* knowledge is being situated and is exchanged/transferred within the social fabric of an expert culture by the principles of observation and imitation. Yet, regarding the transfer of technology, one important challenge has emerged: How can the master's cognitive structures be made accessible to the apprentice? Only such access will allow the apprentice/recipient to assimilate the sender's expertise in the necessary depth and breadth.

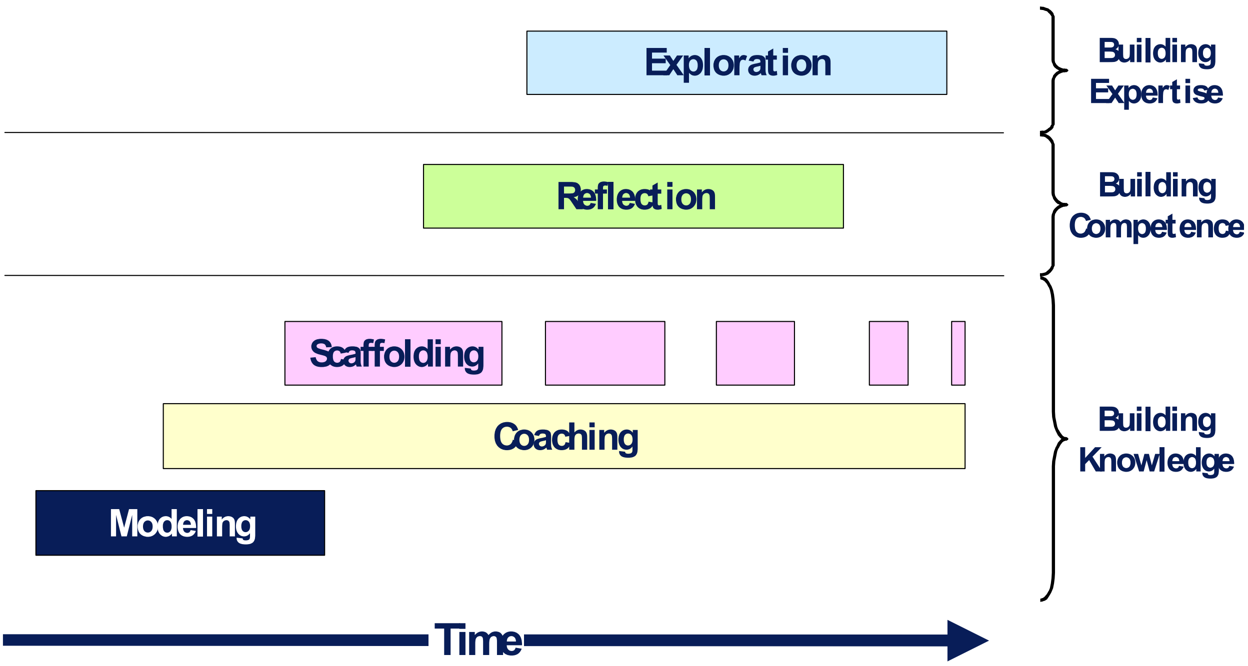
An Action-Oriented Model of a Technology Transfer Process

Applying apprenticeship methods to technology transfer requires the externalization of processes that are usually carried out internally. This problem is tried to be solved by establishing a close and personal interaction between the expert and the learning person. The basic methodology of transfer consists of having the recipient to solve real-world problems in authentic situations (*modeling*). While the recipient is trying to solve the problems, the expert offers help and support only in those instances which are insurmountable by the person learning.

The recipient's learning activities and perceptions are directed by *coaching* and supported by *scaffolding*, i.e. partial involvement in problem solving by the expert. Over time, support is being sequentially reduced which leads to an increased level of self control of the recipient within the process of learning. The expert increasingly fades until the recipient finally reaches the level of expert by him/herself (see figure App5). The recipients acquire knowledge in the social fabric of the expert's culture by *articulation* which causes them the externalize their thinking processes.

Externalization of the thinking processes gives the expert insight into the learner's thinking, allows immediate feedback for correction opens opportunity for a reflection of those processes. Finally, expert's help becoming less and less the recipient gains more and more self confidence and control which enables him in the end to reach the stage of autonomously solving the problems in authentic domains of problems (*exploration*).

Figure App5: An Action-Enabling Model of Knowledge Transfer[18]



Modeling

Modeling means that the various parts and steps of the task of solving a problem are made visible to the learner by the expert. The expert is providing the conduct of the activity but also providing the learner with a task overview that serves as an advanced organizer for future observation sessions with the expert or with others (expert or not) where much of the learning occurs. Thus, the expert serves as cognitive model and assistance for the learner (*advanced organizer*). Succesful modeling helps reducing the time for building up the learner's knowledge base considerably: Instruction of this sort may accomplish a radical reduction in the time

[18] Building knowledge intends to provide to an individual the necessary skills to achieve certain actions at a general level. Competence is different from knowledge in that the term competence signals an ability that goes beyond of just knowledge. Expertise, finally, represents the highest skill level an individual can achieve.

and effort required for skill acquisition, relative to what would be required (by the engineer) proceeding on trial and error alone.

Coaching

By coaching the expert offers the learner specific and situation-specific help, makes suggestions, gives hints and feedback and is directing the learner's attention to the important aspects of the problem solving process. Coaching intends to make the recipient understand and deploy the constitutive elements of expertise. Together, the expert (coach) and apprentice, they develop situations which allow the latter to gain insight into the expert's cognitive processes . A good coach will never solve the learner's problems. His task is to get the apprentice on the right track by asking and listening and developing new insights. The building of new knowledge and problem solving strategies cannot be forced; thus good coaching always makes clear that it is an offer to develop and acquire new knowledge.

Scaffolding and Fading

Scaffolding can be perceived as the process of facilitation which provides structure as well as support. It provides meta-cognitive support by structuring tasks in ways that are beyond the apprentice's skills: determining the problem to be solved, the goal and the way the goal can be broken down into manageable sub-goals. It gives a chance to see how the steps fit together and to participate in aspect of the activity that reflect the overall goals, gaining both skill and a vision of how and why the activity works. Hence, scaffolding is the process of building cognitive bridges so that the expert can engage an apprentice somewhere between what he/she understands already (prior knowledge) and what he/she is on the edge of learning. However, figuring out what an apprentice already knows, and hence what he or she is ready to handle is no trivial task.

Reflection

By reflection a learner is facing the challenge to compare his own thinking and reasoning with the thinking and problem solving strategy of either experts or peers. Those comparisons will help the learner to identify deficits within his or her knowledge bases. Once identified, those gaps can be closed. The interaction between expert and learner leads to questions which provide an adept incentive to make learners externalize their perception and reasoning.

Exploration

Instructions outside of the context of real problems lead to the accumulation of *inert knowledge*. Such knowledge may help to solve problems which are closely related to the original context of instruction. However, in real-world problem solving such knowledge will fail as the learner lacks the necessary application and situation specific aspects of knowledge. To accumulate the meta-cognitive strategies of experts in problem solving the sub-processes of articulation and reflection are of utmost importance as they force the learner to articulate his or her problem solving processes and to compare them with the expert problem solving procedures.

To achieve this de-contextualization in order to create a flexible knowledge base the learner has to deploy multiple perspectives on a specific problem. Such *criss-crossing* (Wittgenstein, 1953) is essential to the development of multiple and flexible knowledge representations which are common to experts, allowing them to understand complex problems and adapting their knowledge on the solving of new problems.

Conclusions

The model proposed here to transfer knowledge from a sender to a recipient may not be the result of thinking which is “new to the world”. Even though the elements of the methodology developed here are not news, their synthesis results in a concept which has proven already valid and solid in single cases of technology transfer. Despite the absence of empirical evidence, some facts are making this approach a more than just plausible approach to design processes of knowledge transfer:

- As such, the transfer is effective. It builds on the fact, that tacit knowledge has to be transferred in interpersonal interaction. It enables the recipient to deploy the knowledge in order to achieve the results which caused his or her interest in the transfer of knowledge/technology.
- The methodology pays attention to the main constituents of each technology transfer – sender, knowledge, and recipient –and the characteristics of those constituents.
- Last but not least, the methodology heavily builds on research developed in cognitive science, cognitive psychology and information processing. Thus, learning is not just situated but also results in the creation of knowledge bases which allow flexible deployment of the knowledge acquired.

However, there is one major disadvantage to the methodology as it is proposed here: Despite being effective, it is rather slow and resource intensive and thus will be questioned by inexperienced managers.

Technical Meeting
to Develop a Guidance Document on the Preservation (and Enhancement) of Nuclear Knowledge for Nuclear Power Plant Operating Organizations,
14-17 June 2004, Vienna, Austria

Report

KM is quite a new concept, having come to prominence during the 1990's. However, due to the nature of NPP operating organizations (high hazard but low risk) a number of plant activities and programmes have been in place throughout the industry to manage and control the knowledge and information related to NPP design, construction, operation and maintenance. Examples of existing KM activities for NPP operating organizations include:

- Configuration management
- Document control
- Work control systems
- Quality assurance and quality management
- Operating experience programmes
- Corrective action systems
- Safety analysis
- Training and development
- HR management

KM implementation is not intended to replace any of these systems, but rather should increase the benefits from these systems through providing an integrated approach to:

1. Increasing the value of existing knowledge
2. Collecting, developing, and integrating tacit knowledge, and
3. Identifying business, operational and safety risks due to knowledge gaps

If properly implemented, KM shouldn't "take over" any existing plant programmes or activities, but rather should be a catalyst to increase the benefits to the organization of these activities. The lessons learned in the nuclear industry in the past 20 years in moving from inspecting in quality through large quality assurance organizations to building quality into all plant processes (with associated reductions in the number of quality assurance auditors/inspectors), have considerable relevance for KM implementation

If we look 5 or 10 years into the future, the success of KM for NPP operating organizations shouldn't be measured by whether or not there is a Knowledge Management Officer or a large KM organizational unit, but rather that KM ideas are a part of the daily life, practices and culture of NPP operating organizations, and that KM methods are being used to make established processes for managing knowledge and information more effective.

A new technical document on Preservation (and Enhancement) of Nuclear Knowledge for Nuclear Power Plant Operating Organizations is under preparation. The document will identify the fundamental elements needed for an effective KM system, as well as providing guidance concerning methods for KM implementation.

This document is intended for senior managers of NPP operating organizations up to and including the Board of Directors. For this audience, knowledge management (KM) should be important because: there is a 100-year or more life-cycle for the knowledge needed to effectively and safely manage an NPP; thus KM needs to be part of the long term strategy of the organization. Additionally, through KM:

- Operational and safety performance can be improved
- Operational and personnel safety risks can be reduced
- Re-engineering opportunities can be identified

Collectively these results should lead to improved business performance.

While there is no universally accepted definition of knowledge management, for the purposes of this document, knowledge management is defined as a systematic process of finding, selecting, organizing, distilling, validating and presenting knowledge in a way that improves an employee's or organization's comprehension in a specific area. For an NPP operating organization, specific knowledge management activities help focus the organization on acquiring, storing and utilizing knowledge for such things as effective transfer of knowledge from an ageing workforce to the next generation, problem solving, dynamic learning, strategic planning and decision making.

The meeting participants made the following recommendations:

1. The IAEA should publish a technical document on this topic, as there is an immediate need for this information at many NPP operating organizations in Member States.

2. Due to the immediate need for this information, the publication of this technical document should be expedited as much as possible.

3. Meeting participants provided inputs for a proposed outline for this technical document. They recommended that the IAEA use this outline as the basis for developing a draft document. Meeting participants indicated that they were prepared to provide further review and comment on this draft, as needed. They also suggested that the draft document be reviewed by a small number of NPP operating organization managers who have not been involved with its development in order to ensure that it is presented and organized in a manner that will be most suitable for the target audience). They suggested an additional meeting to review the document prior to its publication.

4. Meeting participants encouraged the Agency to work closely with other nuclear industry international organizations that are also working on KM. These include: NEI, OECD/NEA, WANO/INPO, and EPRI. For example the Nuclear Human Resource Group (NHRG) Community of Practice under NEI is considering a workshop later this year at INPO Headquarters in Atlanta.

5. Meeting participants indicated that there would be considerable benefit for NPP operating organizations to have access to services to assist in the implementation of the fundamentals and guidelines to be provided in the proposed technical document on knowledge management for NPP operating organizations. The nature of these services could be a combination of communities of practices, benchmarking and assist visits/missions.

6. As developments in KM are moving quite rapidly, both within the nuclear power industry and in other relevant industries, it is recommended that the Agency develop and maintain a data base of examples of good practices in KM, rather than providing them as annexes or appendices in the proposed technical document (e.g., web space with password control). In that way the information can be kept current and quickly reflect new developments in this field. It is suggested that examples be provided in all areas for which methods are discussed in the guidelines, and also address as many application areas as possible (e.g., document control, work control, configuration management, training, HR, OE, corrective action systems).

7. Providing a CD-ROM at the end of the meeting that includes all presentation and reference materials from the meeting is an effective way for participants to have information that may be of immediate use to them in improving their organization's practices in this topic area. We encourage the adoption of this as a standard approach for Agency meetings.

8. It is suggested that the Agency include KM support for the industry in its medium and long term strategies and plans.

Technical Meeting
to Develop a Guidance Document on the Preservation (and Enhancement) of Nuclear Knowledge for Nuclear Power Plant Operating Organizations,
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List of participants

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USA	Mr. Ch. Goodnight	Goodnight Consulting, Inc.
	Mr. T. Mazour	IAEA
	Mr. Y. Yanev	IAEA