SYSTEMATIC KNOWLEDGE TRANSFER BASED ON KNOWLEDGE CORRELATIONS

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The in-house knowledge represents a decisive competitive factor for many enterprises. Employees' amount of knowledge increases and gets more and more interlinked. As well, knowledge is often concentrated at single employees and the fluctuation of employees increases. For these reasons the effective knowledge transfer between employees poses a major challenge for modern enterprises. The new approach to systematic knowledge transfer is based on the acquisition of a mentor's objects and dependencies and a mentee's familiarity with these knowledge objects. This allows deriving relevant knowledge bundles to be transferred to the mentee. The approach requires only little resources, as not the knowledge of a mentor has to be documented but the knowledge structure only. The knowledge transfer can be systematized and the visualization of interrelated knowledge objects increases the workshop efficiency for mentor and mentee.

Keywords: Knowledge transfer, knowledge bundles, structural complexity management, multiple-domain matrix.

1. INITIAL SITUATION

Most enterprises indicate the in-house knowledge as a decisive competitive factor. In this context, the fluctuation of employees means migration of knowledge — which has to be counteracted in order to maintain the competitive position of an enterprise. For this reason, the efficient knowledge transfer between employees represents a demanding challenge for modern enterprises.

Figure 1 shows four main causes for the increasing need of efficient knowledge transfer: Nowadays, employees accumulate more knowledge than in former times. This results from an increasing product complexity [1] and the need for inter-divisional, integrative work. Expert knowledge in one specific field is not sufficient to manage complexity; the need for inter-divisional cooperation e.g. gets obvious in the development of complex mechatronical products.

Not only the amount of accumulated knowledge objects but also the knowledge about the dependencies between these objects increases. Such dependencies are mainly stored in the mind of employees (and make part of their experience knowledge). For example, the object knowledge about a number of products, production sites and customers of an enterprise can be easily documented and transferred between employees. An experienced employee, however, knows that the order of product A by customer B at site C typically results in severe problems. Such knowledge about dependencies increases in a cooperative working environment, does not get documented and therefore is difficult to be transferred between employees.

"Unique knowledge owners" represent another major issue for the knowledge transfer in enterprises. These employees account for important tasks and are the only ones, who possess the required knowledge. Increasing specialization and subdividing of business processes advance the existence of

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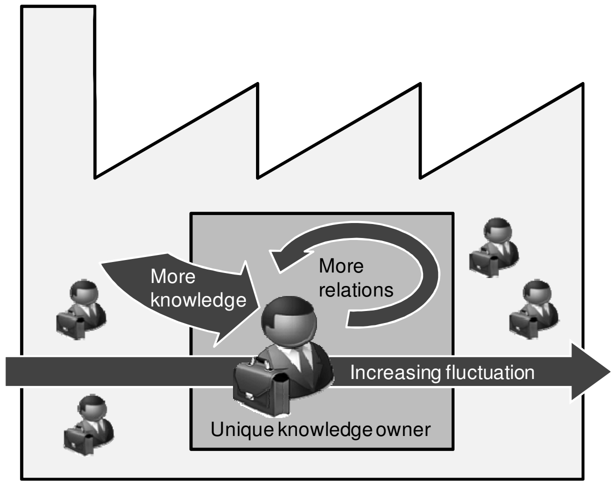

Figure 1. Causes for the increasing need of efficient knowledge transfer.

"unique knowledge owners". If the knowledge of such employees will not get transferred in time, their leaving can result in significant negative consequences for an enterprise.

The increasing fluctuation of employees intensifies the need for knowledge transfer. The fluctuation rate is higher-than-average for specialists and executive staff. At the one hand, the demographic change in most industrialized countries results in an increasing demand for well-trained staff. At the other hand the globalized working environment and the claimed flexibility of employees lead to shorter periods of affiliation with one enterprise. Life-long affiliation with one enterprise disappears. Thus, knowledge transfer will become a standard task required several times during an employee's working life.

2. PROBLEM

Employees collect more knowledge objects with more interrelations than in former times. Additionally, many employees only work for some years in the same enterprise. And some employees are unique knowledge owners, i.e. they are the only ones possessing specific enterprise knowledge. This means that more knowledge has to be transferred (more objects and dependencies), knowledge transfers are required more often (increasing fluctuation) and within short available time slots (retirement of employees can be planned, job changes during the working life become only known some months up-front). In addition, a high quality of transfers must be assured (unique knowledge owners).

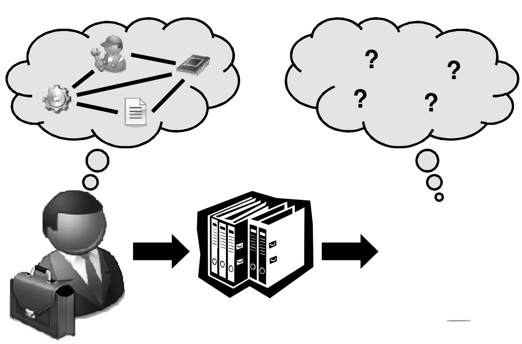

Figure 2. Knowledge transfer by documents without object dependencies.

Figure 2 shows that documented object knowledge can be exchanged between employees. The object dependencies describing the relation between knowledge objects mostly represent implicit knowledge. This is not documented and therefore cannot be easily transferred.

Mentor and mentee could realize the knowledge transfer by working conjointly at projects. However, this does not fulfill the constraint on short available time slots. Enterprises need a method for executing knowledge transfers, which meets the requirements mentioned above: knowledge complexity, short available time slots and high transfer quality.

3. OBJECTIVE

The approach presented here does not aim at the documentation of knowledge, as it is done by several approaches on knowledge engineering [2]. Here, a mentor and a mentee shall be supported while transferring knowledge in workshop discussions. This support shall include the systematic identification of relevant knowledge bundles, knowledge gaps as well as possibilities for an intuitive visualization and user interaction with knowledge objects and dependencies during transfer workshops. Thus, the knowledge itself shall not be acquired; but bundles of related objects and comprehensible checklists for executing efficient knowledge transfers shall be provided.

The general objective can be subdivided as follows: The resources required for the transfer of employees' knowledge shall be minimized. In most cases, not the entire knowledge of a mentor has to be transferred in order to enable the mentee to fulfill the mentor's tasks. For this reason, it shall be possible to focus the knowledge transfer on specific issues. A systematic procedure of knowledge transfer shall assure the completeness of required transfer in order to maintain a high quality of task fulfillment despite employee turnover.

Specific objectives result from the stakeholders' viewpoints: An enterprise wants to reach a high quality of knowledge transfer and to minimize the required resources. A mentee wants to receive relevant, first-hand knowledge, to shorten his training period and to improve his ability of fulfilling important tasks. A mentor is interested in being valued for his knowledge. It must be mentioned that a knowledge transfer can only be executed successfully, if the mentor is interested in its positive results.

4. SCIENTIFIC BACKGROUND

Several scientific approaches concentrate on managing dependencies within complex systems, e.g. Operations Research [3], System Dynamics [4], Data Mining [5] or Systems Engineering [6]. Structural Complexity Management [7] is the basis for the systematic knowledge transfer presented here. This approach considers structural models as input. These models only describe system elements and their dependencies. Quantitative specifications of elements and dependencies as well as the system status, dynamics and behavior are not considered directly. In fact, Structural Complexity Management derives a system's behavior by analyzing the system structure. Even systems comprising many elements and dependencies can be modeled with this approach that allows deriving relevant system parts for closer user interaction, analysis and optimization.

Structural Complexity Management applies matrix-based techniques, which have been introduced as Design Structure Matrices (DSM) [8]. Enhancements allow modeling of more comprehensive systems and are called Multiple-Domain Matrices (MDM) [9].

Most representations of system structures result from automated import of information [10]. If, e.g., the email traffic between employees shall be depicted, structural information can be derived from data bases. However, the representation of objects and dependencies for knowledge transfer does not allow an automated acquisition procedure. The network has to be acquired manually, which implies several challenges to be met: completeness of acquisition, error-proneness, training effects. The MDM is suitable for the manual acquisition of dependencies between elements. The matrices can be combined with graph representations, which depict the same information about elements and dependencies [11]. Especially force-directed graphs [12] can be applied for realizing an intuitive user interaction with a network [7]. The software Loomeo [13] combines matrix and graph representations; with this tool users can acquire dependencies in matrix form and interact with the acquired system structure by using a force-directed graph.

5. APPROACH

The systematic knowledge transfer based on knowledge correlations is systematized in five steps, which will be detailed in the following.

5.1. Acquisition of a mentor's knowledge: objects and dependencies

In the beginning, the mentor's relevant knowledge objects and dependencies have to be acquired. Therefore, relevant knowledge domains have to be determined. Figure 3 shows at the left side tasks, competences, networks and methods. These are four basic knowledge domains applicable for most knowledge transfer situations. Nevertheless, specific situations (specific knowledge of a mentor) might require breaking down some of these domains into sub-domains. For example, the knowledge of a sales director could be very comprehensive concerning the networks domain. Then the subdivision of this domain can be helpful.

The domains are itemized into the knowledge objects relevant for the mentor (right side in Figure 3). The systematic acquisition of these items can be supported by using a common mind map. Knowledge objects mentioned by the mentor can be classified and clearly arranged in such a hierarchical decomposition.

After acquiring the knowledge objects, cross-links are introduced between the domains. Figure 4 shows at the left side generic links leading from all domains to the task domain. The default meaning of

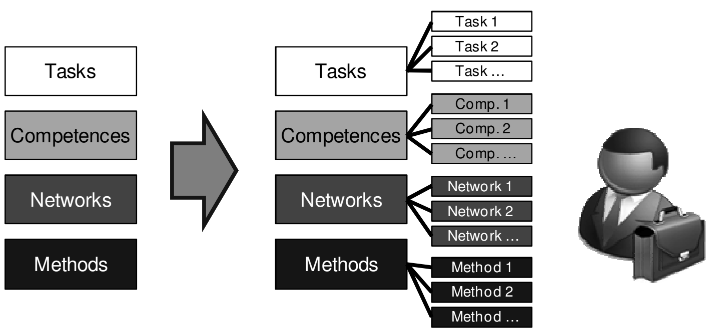

Figure 3. Knowledge domains and assigned knowledge objects.

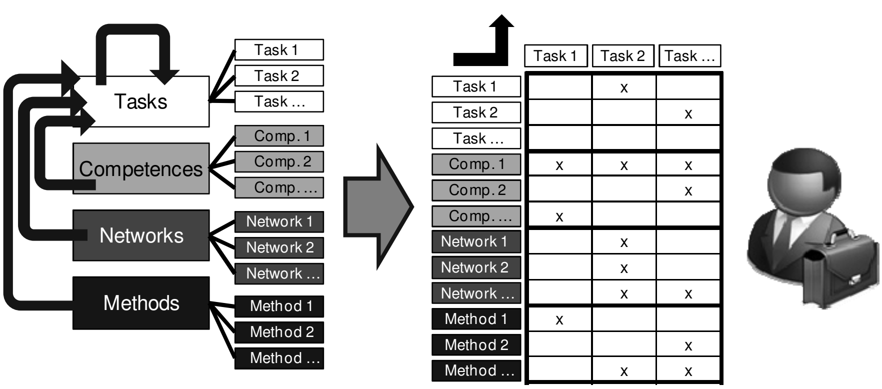

Figure 4. Dependency meanings between domains and detailed dependencies between objects.

these dependencies is “required for”. This means that competences, networks and methods are required for fulfilling tasks. Even tasks can be required for fulfilling other tasks. The default of dependencies between knowledge domains could be adapted depending on the specific situation (knowledge of a mentor). However, the presented model of domains and their dependencies proved to be suitable for a variety of transfer applications. Prior work [14] included additional links from networks and methods to competences. This focus turned out to be of less importance in practice; therefore links leading to competences were not considered in the actual approach.

The right side in Figure 4 shows dependencies between the itemized knowledge objects. Based on the general dependencies between domains (left side), here the mentor has to declare, which knowledge object is required for which task. As it can be seen in the picture, only the existence and not a quantification or explication of dependencies is acquired. That means that not the mentor’s knowledge, but the dependencies between a mentor’s knowledge objects are acquired. This binary acquisition of dependencies instead of detailed knowledge descriptions minimizes the acquisition effort. Nevertheless, it can be a demanding task for the mentor to complete the matrix (due to the amount of matrix cells). Therefore the acquisition should be supported by a moderator.

5.2. Acquisition of a mentee’s knowledge gaps

Once the mentor’s knowledge objects and dependencies have been acquired, the knowledge gaps of the mentee have to be identified. Whereas the acquisition process is demanding and time consuming for the mentor, the mentee only has to invest little effort. As it can be seen in Figure 5, the mentee only has to declare his state of familiarity with the mentor’s knowledge objects (typically in binary form). Dependencies between knowledge objects have not to be considered here. Thus, the mentee can easily process even a large quantity of objects within few hours of work.

5.3. Creation of knowledge bundles

Relevant knowledge bundles can be identified based on the mentor’s information about knowledge objects and dependencies and the mentee’s information about his familiarity with the knowledge objects. Such bundles contain knowledge objects, which need to be transferred in combination with each other. For example, the mentee is not familiar with three methods required for fulfilling a specific task. Only if all three tasks are transferred the benefit (ability to fulfill the task) can be reached. Thus, knowledge bundles contain all content relevant for a transfer in order to achieve a specific benefit.

Two different use cases for creating knowledge bundles can be identified (Figure 6). In use case a (left side) the mentee is not familiar with a specific task. Then it is important to identify associated enablers (competences, networks, methods), which are also unknown to the mentee. The dependencies acquired with the mentor depict which enablers the mentor requires for fulfilling the task. Consequently,

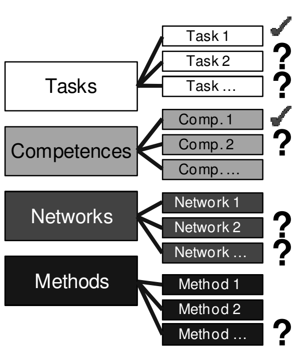

Figure 5. Familiarity of a mentee with the mentor’s knowledge objects.

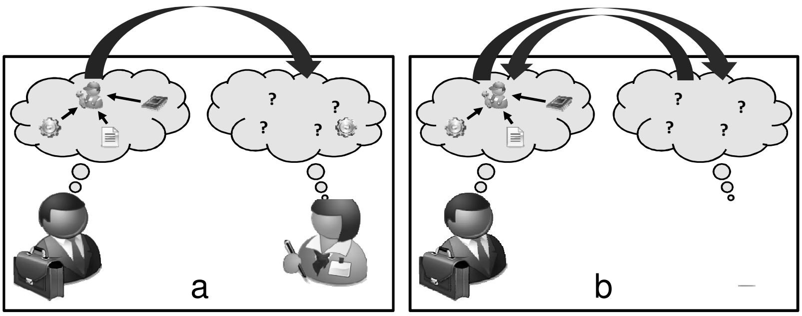

Figure 6. Use cases for creating knowledge bundles.

a knowledge bundle includes the mentee's unknown task and unknown enablers the mentor declared as important for fulfilling the task.

In use case b (right side in Figure 6) mentor and mentee are both familiar with a specific task. However, the mentor mentioned enablers for this task, which are unknown to the mentee. In other words, this constellation describes that mentor and mentee both fulfill a specific task, but that they have different enablers at their disposal. Then a knowledge bundle contains the task in question and the mentor's enablers, which are unknown to the mentee. The bundle can serve as basis for generating a best practice for task fulfillment.

Figure 7 shows two knowledge bundles. At the left side the mentee is not familiar with "Unknown task 1". The knowledge bundle contains those enablers the mentor declared as necessary for fulfilling this "Unknown task 1" and the mentee declared that he is not familiar with these enablers. Thus, the successful transfer of "Unknown task 1" must include the transfer of two competences, three networks and one method. The depiction of this knowledge bundle can be applied as a check-list in workshop discussions.

Two extreme cases exist for knowledge bundles of unknown tasks and enablers (left side in Figure 7): On the one hand, a mentee is not familiar with a task, but he possesses all required enablers. Then the knowledge bundle only contains the task, which can be "learnt by doing". Apparently, the mentee never executed the task, but he holds all required enablers. On the other hand the knowledge bundle contains an unknown task and many unknown enablers. That means that the mentee would need to learn many enablers before he would be able to fulfill the task. The mentee lacks the background of a task and it can be doubted that he is the right person to execute it in the future. Mentees with a different professional background than the mentor often face that problem.

At the right side of Figure 7 the mentee is familiar with "Known task 1". The mentor declared several enablers (one task, one network, one competence, two methods) as necessary for fulfilling this "Known task 1". These enablers are unknown to the mentee; consequently, he fulfills "Known task 1" with a different background than the mentor. In such a case the mentee does not require a transfer of knowledge, but mentor and mentee should discuss the best practice for fulfilling "Known task 1".

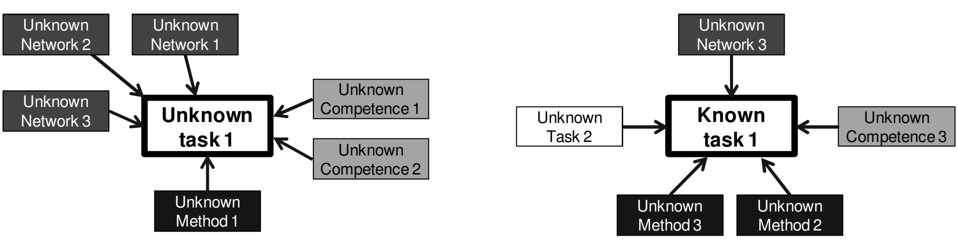

Figure 7. Exemplary knowledge bundles in graph representation.

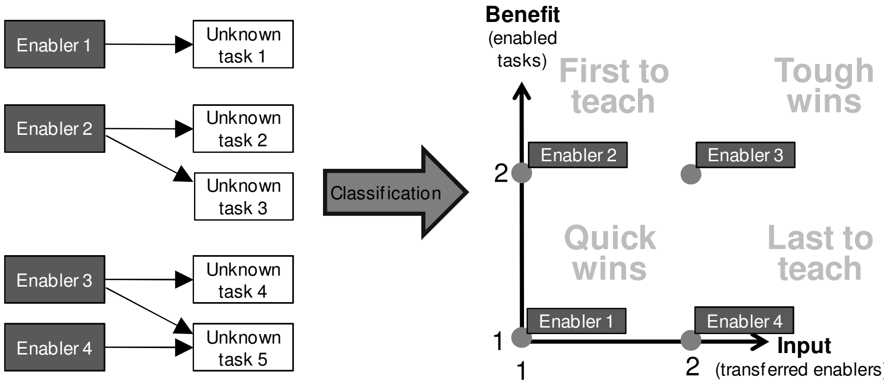

Figure 8. Rating enablers by the Input-Benefit-Diagram.

5.4. Prioritizing enablers for detailed consideration

Knowledge transfers often have to be executed within short time slots. In such cases the transfer of all relevant knowledge is impossible and a method for prioritizing the most important enablers is required. Concentrating on those enablers assures the best possible transfer process under the given time constraints.

The minimization of input in combination with a maximization of the output represents a suitable rating criterion. Enablers are most important for the transfer, if they allow the mentee to fulfill the highest quantity of tasks. Figure 8 visualizes this rating method. The Input-Benefit-Diagram depicts the amount of required input (i.e. the amount of transferred enablers) on the horizontal axis. On the vertical axis the resulting benefit (i.e. the amount of new tasks the mentee can execute) is noted, which corresponds to the input. The diagram possesses four sectors, which characterize the enablers as follows: first to teach, quick wins, tough wins and last to teach.

If one enabler is required for learning one unknown task, this enabler represents a quick win in the diagram, as one single input (transferred enabler) leads to one benefit (enabled task). If one enabler is required for learning two (or more) tasks, the same input leads to a higher output. The enabler can then be characterized as “first to teach”.

Rating Enabler 3 and Enabler 4 is more complicated: Enabler 3 is required for two unknown tasks; but even if Enabler 3 gets transferred Enabler 4 is still required in order to enable the mentee to learn Unknown task 4. That means that the transfer of Enabler 3 only enables the mentee to learn two tasks, if Enabler 4 gets transferred as well. Thus, Enabler 3 gets characterized as “Tough win” in the diagram, because a high benefit (two enabled tasks) can only be realized with a high input (two transferred enablers). Finally, Enabler 4 is required for learning the Unknown Task 5; but therefore Enabler 3 is required in addition. That means that the isolated transfer of Enabler 4 would not even enable the mentee to learn one task. Consequently, Enabler 4 is characterized as “Last to teach” in the Input-Benefit-Diagram.

5.5. Visual support of transfer workshops

The intuitive visualization and access to the knowledge bundles support mentor and mentee in their direct knowledge transfer and serves as checklist. For the application in workshops it must be possible to extract one specific knowledge bundle and to easily switch between different ones. After discussing specific elements it must be possible to remove them from the depiction or to add comments for later discussions.

In the approach presented here force-directed graph representations are applied for interacting with knowledge bundles in workshops. For example, the software Loomeo [13] allows the import of knowledge networks and intuitive user interaction. The visually supported discussions between mentor

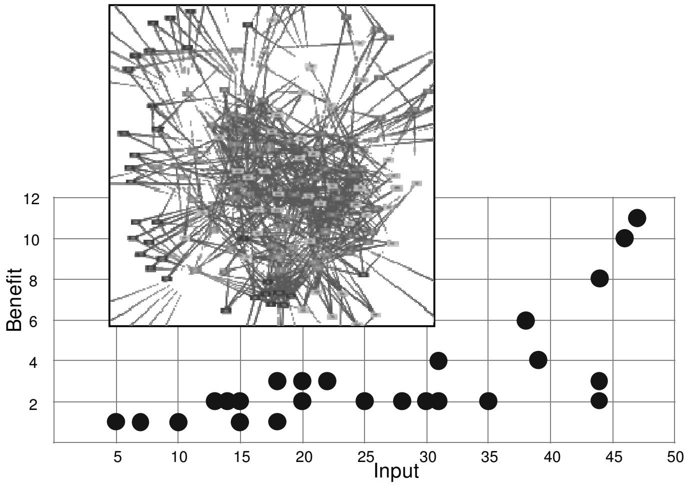

Figure 9. Extract of a mentor's network and rating by Input-Benefit-Diagram.

and mentee become well structured and more efficient by sequentially browsing through the graph visualization of knowledge bundles.

6. CASE STUDY

The approach has been applied to several knowledge transfers in industry. The investment for acquiring the mentor's network, the mentee's knowledge gaps and for prioritizing knowledge bundles summed up to seven man days per transfer. After these preparations the transfer workshops started. The support by visual representation of and interaction with relevant knowledge bundles turned out to be helpful. Mentors and mentees attested the target-oriented and well-structured discussions based on the depiction.

Figure 9 shows an extract of the mentor's knowledge network. This was captured during a knowledge transfer that was initiated in a mid-sized enterprise, which develops and produces mechatronical products. The mentor's background was mechanical engineering; during the last years of his employment he conducted several projects in continuing education of sales employees. More than 180 objects were linked by more than 1000 dependencies. In addition, parts of the Input-Benefit-Diagram are shown.

The mentee's background was from industrial engineering. The closely related education of mentor and mentee explains the many enablers located in the lower left area of the diagram. These "quick wins" mean that little transfer of some competences, networks and methods allows the mentee to fulfill several new tasks. Notable outliers are the enablers located in the lower right corner of the diagram. These "last to teach" enablers result from the mentor's engagement in educational tasks. For being able to fulfill these "off topic" tasks, many knowledge objects would have to be transferred. It seemed worth to consider transferring these tasks to another mentee with more appropriate background.

7. CONCLUSION AND OUTLOOK

The presented approach on systematic knowledge transfer based on knowledge correlations tackles a challenge of major importance. Networked knowledge and fluctuation of employees increase. In conjunction with globalization trends and demographic changes in industrial countries this results in increasing importance of efficient knowledge transfers. The advantage of the presented approach is its little need of resources. The mentor's knowledge is not required to be documented, but mentor and mentee obtain knowledge bundles that support the efficient knowledge transfer by discussion. The method of creating knowledge bundles and their rating by required input and achievable benefit proved to be useful especially under hard time constraints. Future research will focus on the enhancement of considered knowledge domains and the improvement of prioritizing knowledge bundles (consideration of further constraints).

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