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MEASURES AND METHODS FOR SYSTEMATIC KNOWLEDGE MANAGEMENT

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1. Introduction

The employees‘ knowledge is the essential success factor for technology-intensive companies [Nonaka and Takeuchi 1995], [Probst et al. 2000], especially within knowledge-intensive processes such as the engineering design process (cp. [Wallace et al. 2005]). Knowledge allows for developing new technologies as well as their integration into innovative products. Hicks et al. [2002] illustrate how knowledge is used and required in the design process.
There is a continuing change within the knowledge: On the one side fluctuation of employees and demographic change determine a need for preserving the knowledge. On the other side, new disruptive technologies have to be developed in order to design and deliver competitive products and services in the future. The need for interdisciplinary collaboration, especially in development projects, rises due to the continuing integration of information and communication technologies as well as services in market offers.

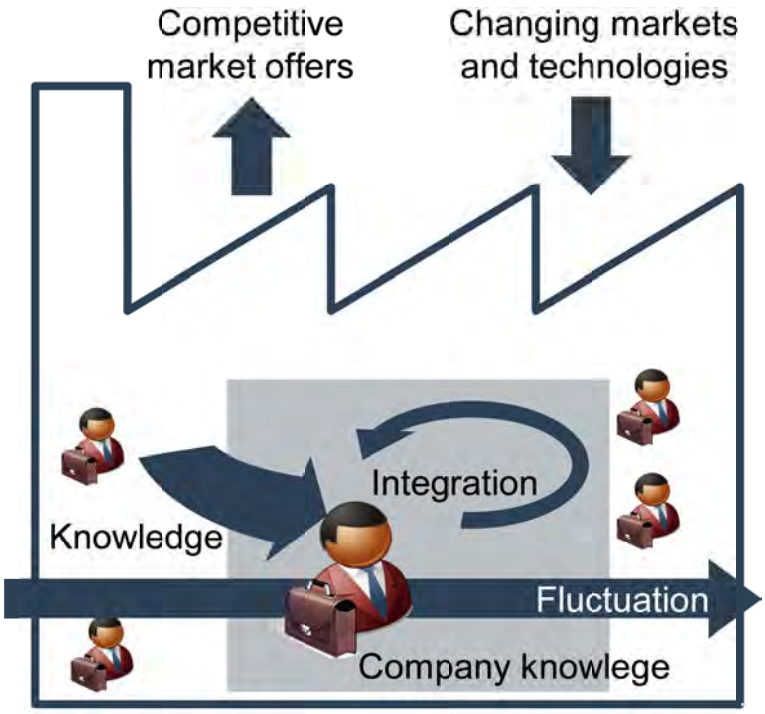

Figure 1. Knowledge-related challenges for industry [Maurer and Kesper 2011]

To cope with these challenges there is a need for developing a company's knowledge. Developing means preserving the existing knowledge as well as creating new required knowledge. If knowledge is becoming obsolete, developing also means losing of knowledge. This paper contributes in an approach for selecting appropriate measures and methods for the knowledge development. Within the core of our interest is the knowledge stored internally in human memory, what embraces according to Wallace et al. [2005] explanations, understanding and intuition about processes and products.

2. Research methodology

The goal of this research was to develop a methodology for selecting goal-oriented measures and methods for systematic knowledge development. The basis is a methodology for analyzing the demand for developing knowledge described by Wickel et al. [2013] and Schmidt et al. [2013].
Within a literature study, we have collected an exhaustive collection of 3 strategies, 40 measures and 69 methods for knowledge development. Based on the experiences of three industrial cases studies, we have derived eight approaches for selecting appropriate measures. These assumptions have been verified by expert interviews with a senior knowledge manager from an electrical goods company as well as with a junior knowledge management consultant.

3. Systematic development of knowledge

For defining goal-oriented measures and tools for developing knowledge, the demand for that has to be analysed thoroughly. Therefore a MDM-based methodology was introduced by Wickel et al. [2013] and Schmidt et al. [2013]. This section integrates that methodology into an approach for the systematic development of knowledge. The output is a set of chosen measures and methods for developing the knowledge (see section 5).
The as-is and to-be knowledge is documented in a knowledge map. Knowledge maps represent knowledge graphically [Eppler 2001]. There are several types of knowledge maps: knowledge source maps (Which employees provide a knowledge element?), knowledge application maps (What knowledge is required to perform a task?), knowledge structure maps (global architecture of knowledge) knowledge development maps (What knowledge is required in the future) [Eppler 2001].
For that specific approach multiple domain matrices (MDM) are used for a knowledge map. The meta-model of the MDM is depicted in figure 2. It consists of three domains: tasks, knowledge and employee. According to Eppler's classification of knowledge map that MDM-based knowledge map consists of several distinct types. The domain mapping matrix (DMM) employee-knowledge is a knowledge source map, the DMM task-knowledge a knowledge application map and the overall MDM a knowledge structure map. The measures and methods are derived from a knowledge development map, achieved by analysing the differences between as-is and to-be knowledge.

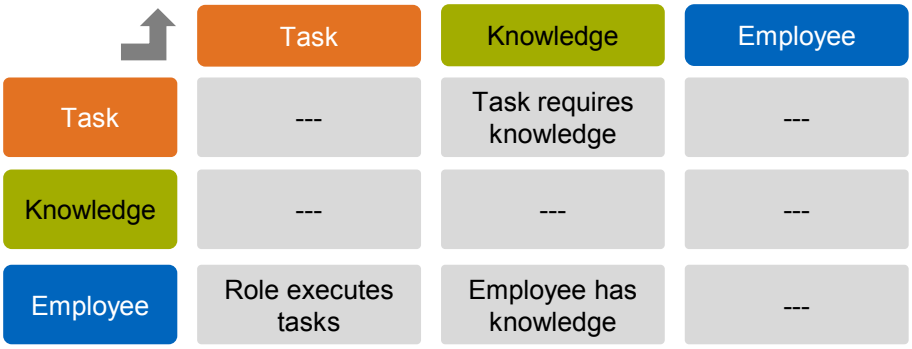

Figure 2. Meta-model of knowledge map [Wickel et al. 2013]

The approach for the systematic development of knowledge consists of four phases:

1. Definition of goal and boundaries (section 3.1)
2. Acquisition of as-is knowledge map (section 3.2)
3. Acquisition of to-be knowledge map (section 3.3)
4. Definition of measures for developing the knowledge (section 5)

3.1 Definition of goal

Within the first phase, the goal for developing the knowledge is defined (see figure 3 left). Possible objects are departments or products where a discontinuity for the knowledge can be anticipated. An example is the introduction of a new technology, for example the transition from fuel-powered cars to battery electric vehicles that need for new competencies in developing batteries and electric engines whereas the knowledge for developing internal combustion engines is becoming obsolete. Another example is the servitization of products when transforming into a product-service system (PSS) provider as discussed by Tan et al. [2007]. On the basis of the defined objects relevant employees are chosen that are considered for the acquisition of the knowledge map. Furthermore, the system boundary is defined, meaning for example to explicitly define which employees are not considered.

3.2 Acquisition of as-is knowledge map

The as-is knowledge map is acquired within the second phase by setting up a MDM, as depicted in figure 2. For setting up the knowledge map the tasks and knowledge of the employees is collected in a workshop by card technique (cp. figure 3 right). On that basis an as-is knowledge map is set up for each employee individually. The DMMs employee-task and task-knowledge are acquired directly; the DMM employee-knowledge is derived from that. The whole as-is knowledge map is calculated by summing up the knowledge maps of each employee (cp. [Wickel et al. 2013]).

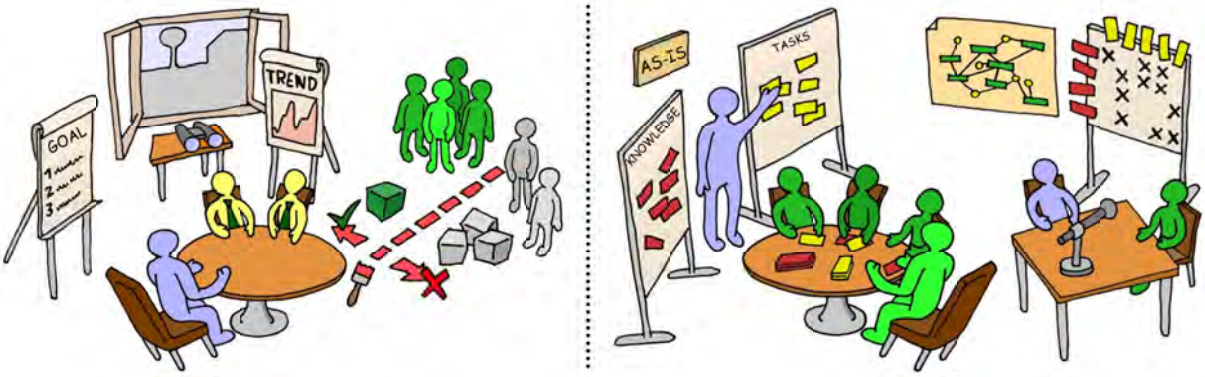

Figure 3. Definition of goal (left), acquisition of as-is knowledge map (right)

3.3 Acquisition of to-be knowledge map

In the next step, the to-be knowledge map is set up (cp. Schmidt et al. [2013], figure 4 left). For being able to compare the as-is and to-be knowledge maps, the to-be knowledge map is developed on the basis of the as-is knowledge map. Thus, the granularity and terminology of tasks and knowledge elements is similar.

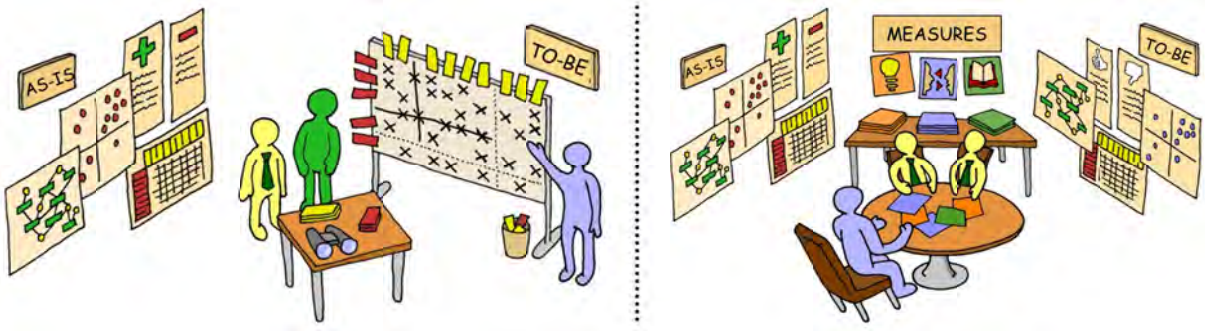

Figure 4. Acquisition of to-be knowledge map (left), definition of measures (right)

Firstly, a scenario has to be set up. The basis for the scenario is the discontinuity as defined in the first phase, the definition of goals. Together with managers or lead employees, it is defined how to cope with or enable the discontinuity. The tasks and knowledge elements are updated for the scenario,

meaning new tasks and knowledge elements are added and obsolete tasks and knowledge elements are ceased. The relations within the MDM are defined, modelling the to-be knowledge structure. The to-be knowledge map is analysed regarding knowledge-related chances and risks for the company as described by Schmidt et al. [2013]).

3.4 Definition of measures for developing the knowledge

On the basis of the to-be and as-is knowledge map, measures and methods for developing the knowledge are defined. An approach therefore is described in section 5. The next section clarifies the terms measures and methods in the context of knowledge management and gives examples.

4. Strategies, measures and methods for knowledge management

There are three strategies for developing the knowledge within a company (cp. [Gretsch et al. 2011]):

- **Knowledge generation.** Required knowledge that is not available within the company has to be generated. This can be done for example by creativity techniques, acquisition of new employees or professional training.
- **Knowledge communication.** Communication aims for sharing knowledge within a company so that a specific employee has access to it in a specific situation where he requires the knowledge.
- **Knowledge documentation.** For preserving knowledge for the future or making internal knowledge explicit, knowledge documentation is a possibility. Furthermore, documentation enables to transfer knowledge from outside into a company.

The applicability of the knowledge strategies is clarified in figure 5. A specific employee is in the centre of the model. In his surrounding there are two types of knowledge carriers (person or document as a specific knowledge element): company-internal and company-external ones. The second dimension is time, which depicts the chronology of the strategy. The correlations are explained below.

Knowledge generation allows for

- (1) transferring company-external knowledge into the company (defined from the company's perspective).
- (2) creating new knowledge.

Knowledge communication allows for

- (3) sharing knowledge company-internally.

Knowledge documentation allows for

- (4-6) documentation of knowledge in the past by the employee himself or company-internal or -external knowledge carriers, allows for using the knowledge in presence.
- (7+8) documentation of knowledge in present allows for future usage, both company-internal and external.

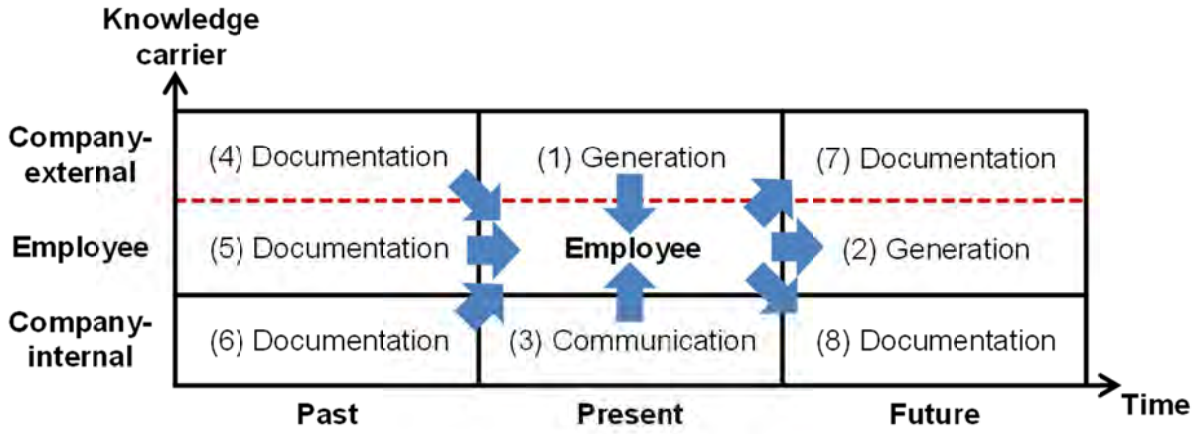

Figure 5. Knowledge strategies

These strategies are realized by **measures** that describe the content how to realize a strategy. For example the strategy "knowledge generation" can be implemented by self-study, professional training, coaching as well as hiring new employees. The practical implementation of these measures is described by **methods**. These methods are guidelines for achieving a defined knowledge management related goal. There are several methods for implementing a measure, but a single method can also be used for the implementation of several measures.
We identified 40 measures and 69 methods for knowledge development and documented them in a catalogue. An excerpt is depicted in Table 1.

Table 1. Expert of catalogue with measures and methods for knowledge development

Measure (40)	**Strategy**	**Methods (69)**	**Goals**
Self-study	Generation	Job shadowing, cyclopaedia, media centre, web based training	Employees are facilitated to acquire knowledge
Transfer of responsibilities	Generation	Job enrichment	Qualification of employees for new tasks
Project management training	Generation	Workshops, coaching, scenario technique, distance learning	Increase efficiency and effectiveness of projects
Knowledge-enabling organization	Communication	Corporate university, communities of practice, intellectual capital report	Enable communication processes within the company
Learning by teaching	Communication	Communities of practice, learning communities, coaching	An employee trains another employee, enhances cooperation
Project documentation	Documentation	Cyclopedia, corporate wiki, media center	Documentation of problems and solutions to solve them
Process Instructions	Documentation	Best practice, lessons learned	Knowledge is made explicit and available for co-workers

5. Approach for selecting measures based on analysis

In this section we describe our approach to integrate the investigated strategies, measures and methods from section 4 with the systematic analysis of corporate knowledge discussed in section 3. Based on significant properties of both as-is and to-be knowledge maps, some measures are more appropriate than others. If, for example, only two employees actually have a knowledge which becomes more important in the to-be state, this element should be built up.
Figure 6 illustrates the approach of depicting the right strategies, measures and methods from the available catalogue. In the first step we apply **eight approaches** reducing the possible measures for each knowledge element individually and make first suggestions for specific method application (see section 5.1). After that, the remaining measures and methods are sequenced by attributing **criticalities** to them (see section 5.2).
As the approach of handling so many measures and methods with several employees quickly gets highly complex, we propose to support the shown proceeding by a computer-based tool. For the application of our process in three industrial use cases we developed a tool written in Microsoft SharePoint which integrates the recording of employees, their tasks, knowledge and dependencies.

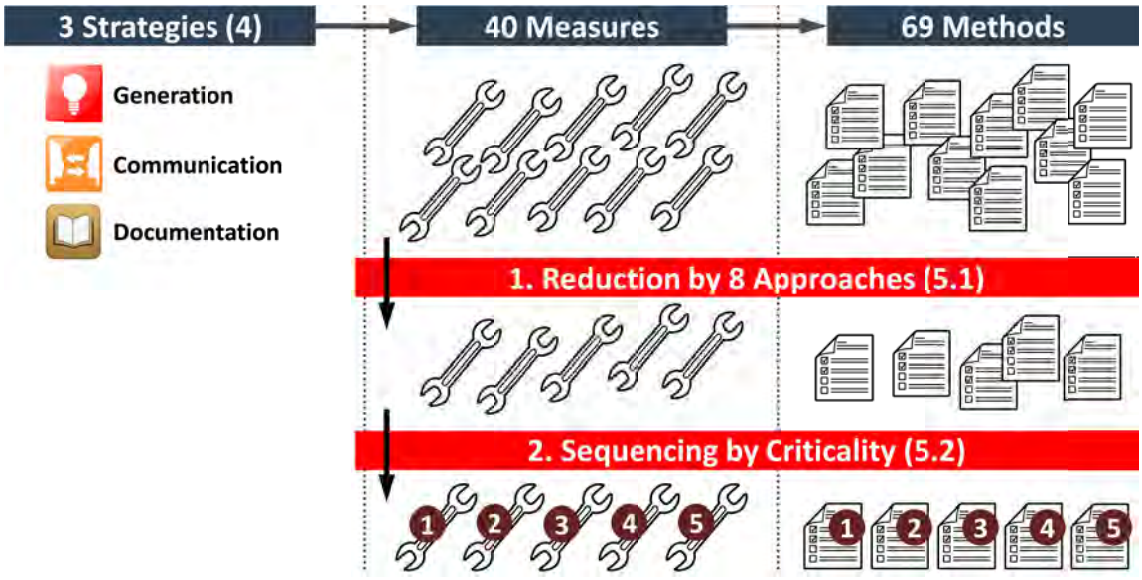

Figure 6. Steps for reducing and sequencing measures and methods

5.1 Linking measures with knowledge maps

We developed eight approaches to derive recommendations for selecting specific strategies, measures and methods or to exclude some of them. The approaches are drafted in a way that they can be easily implemented in a computer-based tool by using *if...then* conditions. By applying the eight approaches the software automatically reduces the available measures and methods for each knowledge element. Thereby, the selection of the right methods can be simplified.

1st approach – knowledge with increasing importance

«Knowledge elements that are rated higher in the to-be knowledge map should be built up».
A high difference of as-is and to-be state leads to a high importance for development of the knowledge element which is represented by an appropriate criticality, described in section 5.2.
Example: If currently two employees know how to run a finite elements simulation and this knowledge gets more important in the chosen scenario, then this knowledge should be developed – by external trainings, new experts or by communications methods which allows other employees to learn from the two knowledge carriers.

2nd approach – tasks with increasing importance

«Knowledge necessary for tasks getting more important in the scenario must be developed».
This approach is similar to the first one. If more employees will be responsible for tasks in the future compared to the current state, the knowledge elements required for these tasks need to be developed.
Example: Actually two employees must handle with cost calculations and therefore need the knowledge of accountancy. If this task becomes more important in the future and more employees need to perform it, then the corresponding knowledge must be built up, for example by external trainings or by applying communication methods.

3rd approach – kind of knowledge

«The kind of knowledge that needs to be developed influences the applicability of measures».
We distinguish four kinds of knowledge according to [Wickel et al. 2013] which can be impacted by specific strategies and measures:

- **Expert knowledge.** Expert knowledge is universally applicable and not company- or product-specific. Engineers acquire that knowledge typically within their education. Examples are knowledge about engineering mechanics or numerical simulation. This knowledge can be

impacted by external training courses or off-the-job trainings. New employees from university, other companies or branches can be hired to expand this knowledge.

- **Procedural knowledge.** Knowledge about technical and organizational processes such as development processes, manufacturing processes or certification processes. This knowledge can hardly be impacted by external sources as it is mostly company-specific but by building up the knowledge internally (creativity) or by communication or representation measures in order to spread the existing knowledge within the company.
- **Product knowledge.** This knowledge is related to the product such as applications, functions, design principles and design rationales. It embraces all experience and information about the company specific product and service portfolio. This knowledge can be enlarged by company-internal research and creativity and by benchmarking with competitors.
- **Network knowledge.** Knowledge regarding contacts of other departments within the company as well as suppliers etc. In order to build up this knowledge communication measures can be applied as well as representing existing networks by means of knowledge maps and contact databases.

4th approach – common task profile

«Employees with a shared task profile can exchange knowledge by communication strategies».
If a knowledge element needs to be developed and one of two or more employees conducting multiple tasks together is an expert in this field, he or she can share his knowledge with the others by applying measures supporting the communication.
Example: The comparison of as-is and to-be knowledge maps shows the need for enlarging the knowledge of Chinese language within the company. One of two collaborating designers is originally from China. They could be seated in the same room and speak Chinese in order to transfer the knowledge to the second designer.

5th approach – singular knowledge

«Knowledge elements owned by only one or two employees should be documented».
If only few employees have certain knowledge and these employees fall out due to illness or fluctuation, the danger exists that there is an abrupt lack of the knowledge leading to a crisis. In order to prevent this danger, this knowledge should at least be represented by means of web- or paper-based documentation.
Example: If only one employee has the knowledge of suppliers and their contact information, he should document the connections in a knowledge map and the contacts in an address file.

6th approach – singular tasks

«Knowledge that is necessary in tasks performed by few employees should be documented».
If only few employee have a task which they need a specific knowledge for, then this knowledge should be represented. If the responsible employee falls out temporarily, then a substitute colleague should at least have the opportunity to inform about the necessary knowledge.
Example: If only one employee has the task of controlling costs of a project and therefore needs the knowledge about calculation, he should represent it by writing manuals for the case that he falls out and another colleague must stand in.

7th approach – knowledge for new tasks

«Knowledge necessary for new tasks on the to-be knowledge map must be developed».
If new tasks need to be performed in the scenario, knowledge that is necessary for these tasks must be built up. In this case it is important to check if new knowledge elements need to be added to the knowledge map and if the available employees could already have this knowledge.
Example: If employees of a service department get the new task of running internal trainings, they need to develop their skills in presentation. If this presentation knowledge element was not recorded in

the knowledge map, the employees must be interviewed again as maybe some of them might already be presentation experts.

8th approach – omitting tasks and knowledge

«Knowledge and tasks that get eliminated in the scenario can be disregarded».
Knowledge that is judged as not relevant in the to-be knowledge map and knowledge that is exclusively necessary for an obsolete task does not have to be developed at all. This is important for the following calculation of criticalities.
Example: A car manufacturer who decides to exclusively develop electric cars will not need the knowledge for combustion engines in the future, so this element does not need to be developed, even if it is affected by another approach.

5.2 Concentrating on the most promising measures

After the application of these approaches, there are still many possible opportunities for developing knowledge. In order to concentrate on the most promising ones, every knowledge element gets an individual criticality derived from the approaches. This criticality can be set for the knowledge element in general (e. g. 1st approach) or only regarding a specific strategy, measure or method (e. g. 3rd approach). Criticality is defined as (1) the need for development of a knowledge element (how important is it to enlarge the knowledge?), (2) the ease of impacting the knowledge element by measures (how easy can a knowledge be developed?) and (3) the unambiguity of correlating knowledge elements with measures and methods (how clear is the link between knowledge and measure?). After determining the criticalities, an operator can concentrate on the measures with the highest criticalities. Table 2 shows the impact of approaches on the criticality.

Table 2. Impact of approaches on the criticality of measures

#	Approach	Criticality
1	Knowledge with increasing importance	Relative distribution: the knowledge element with highest delta between to-be and as-is state gets +10, other elements a lower value (+0 for no difference).
2	Tasks with increasing importance	Relative distribution: knowledge elements necessary for tasks with highest delta get +10, other elements a lower value (+0 for no difference).
3	Kind of knowledge	This approach impacts the criticality of the knowledge regarding a specific strategy, measure or method based on the kind of knowledge (between -10 for not fitting at all and +10 for well-fitting measure).
4	Common task profile	Relative distribution for the correlation of knowledge and communication strategy based on the overlapping degree of task profile of two employees, if only one of them has this knowledge (max. +10)
5	Singular knowledge	Every knowledge element that only one employee possesses get +10 criticality regarding documentation strategies. If two employees possess a knowledge element, it obtains +5 on the criticality regarding documentation.
6	Singular tasks	Every knowledge element necessary for tasks that only one employee has gets +10 criticality regarding documentation. If two employees have a task, the corresponding knowledge obtains +5 on the criticality regarding documentation.
7	Knowledge for new tasks	In addition to the 1st approach knowledge elements for new get another +5 criticality concerning generation strategies, as they actually are not available.
8	Omitting tasks and knowledge	Knowledge elements that omit in the to-be knowledge map get a -1000 criticality as they will not be necessary in the scenario any more. Thereby they will not be developed in any case considering criticality.

The approaches and corresponding criticality values were applied and refined in the three different industrial use cases. We discussed the outcome of our approach with different responsible employees (mostly the managers) and adjusted the criticalities to the mentioned values to get an optimal result.

6. Industrial case study

We evaluated the approach within three different industrial use cases from German engineering companies. We applied the overall approach of developing knowledge (cp. [Wickel et al. 2013]) from defining goals, defining as-is and to-be knowledge maps to the derivation of measures and methods (cp. figure 3 and 4). In the following we describe the last of these case studies as the methodology was refined throughout the two others, resulting in the procedure described in this paper. As knowledge management data within companies is highly confidential, we only show generalized data.

6.1 Goal, as-is and to-be knowledge map

The surveyed global enterprise selected the strategy division which is also responsible for knowledge management as a pilot department to apply the procedure. In preparation for implementing measures and methods the methodology operators and managers defined project goals and created as-is and to-be knowledge maps of the department together with the employees.

Definition of goals

In a first meeting the operators of the methodology gave an overview on the process to the department manager and a lead employee. Together they defined a rough scenario for the department: Currently the department offers support regarding process, project and knowledge management to other divisions mainly in Germany. The division assumes to get more governance within the company so the employees can request the application of processes and management tools. The range of their impact will increase to a global level in the scenario. The department manager decided for seven cooperating employees to take part in the case study.

Acquisition of as-is knowledge map

In a workshop these seven employees gathered and clustered 33 tasks they perform during their daily business. Furthermore, they gathered 47 knowledge elements which are necessary to fulfil the tasks. In single interviews each employee selected the tasks and knowledge elements he or she possesses and marked in a matrix the correlation between these two domains: which knowledge is necessary for which task? From these matrices knowledge maps were derived based on the MDM approach.

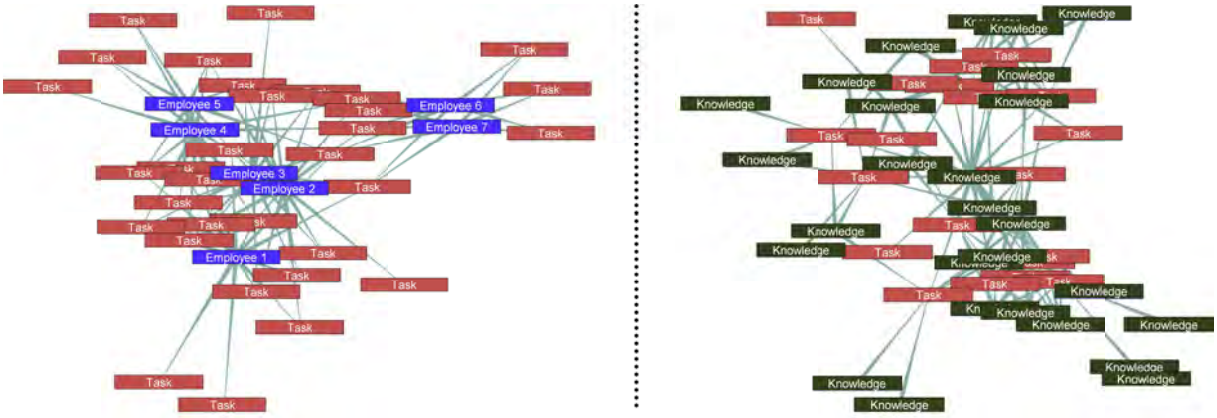

Figure 7. Employee task structure (left), knowledge map of single employee (right)

Acquisition of to-be knowledge map

Based on the as-is knowledge map the manager and a lead employee made adjustments in order to meet requirements from the chosen scenario. For example the increasing global governance requires improved communication and intercultural skills, an increasing knowledge in project and process management knowledge leading to a reduction of tasks and knowledge beyond these areas. Based on the as-is and to-be knowledge maps several analysis tools were applied to generate a SWOT analysis – showing strengths, weaknesses, opportunities and threats of the given scenario.

6.2 Derivation of measures and methods

In the final step measures and methods were derived using the described procedure in this paper in order to face the challenges from the SWOT analysis. We used a computer-based tool coded in Microsoft SharePoint which applies the eight approaches and calculates criticalities automatically based on the knowledge maps data. The tool allows reducing the possible solution space for measures and methods to an adjustable criticality level. Table 3 shows the knowledge elements and corresponding measures with the highest criticality for one selected employee.

Table 3. Highest recommended measures and methods based on the approaches

Crit	Knowledge element	Measures	Methods
24	English	Self-study, systematic change of workspace, in-house training, communication training	Job shadowing, cyclopaedia, media centre, web based training, training near the job, job rotation, coaching
23	Conflict management	Advanced training, mentoring by experienced colleague, transfer workshops	Learning communities, training on-the-job, mentoring, knowledge audits, best practice sharing, storytelling, mentoring
19	Internal databases	Procedural rules, experience reports, internal trainings	Blue pages, communities, open-space technology, lessons learned, ontologies

7. Conclusion

We applied and refined the procedure in three different industrial case studies. The results have been discussed after applying it with the responsible representatives of the companies. They judged the approach as a good tool for managers to get a feedback on the real task profile of the department – their expectation towards tasks and required knowledge elements differed from the real situation more or less in every survey department.

The systematic and thereby rather objective process from setting goals to recommending measures was evaluated as a great advantage compared to existing knowledge management approaches when the outcome highly depends on an operator's experience and skill. In particular the mentioned strategy department responsible for knowledge management was appreciative of the collection of strategies, 40 measures and 69 methods which they could not find in that dimension.

We got different feedback regarding the abstraction level and recommendations for measures. One company mentioned that the limitation and sequencing of measures and methods is appropriate and valuable as a preparation, but it cannot replace an experienced operator who finally selects the most important and suitable measures and executes them. For that reason the company plans to expand their knowledge management competencies. Another company judged the recommendations as sufficient and the abstraction level as appropriate to plan further training programs on its own.

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