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EVALUATION OF KNOWLEDGE TO FUTURE-PROOF THE KNOWLEDGE BASE

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1. Introduction

Enterprises must possess the needed knowledge to design and provide complex and functional products and services. Knowledge is declared as retain knowledge, comprehension and problem solving, employees need to fulfil their tasks for providing products and services. As varying technologies and user requirements change the products and the products' functionalities, the design knowledge has to change too because it is necessary for developing these products. Therefore, company's knowledge has to be up to date to ensure that knowledge is available in the company for designing products. Knowledge management deals with this problem of determining an adequate knowledge basis of an organisation unit, for example a company or a department. The processes of knowledge management can be seen as a control loop of control engineering. The available knowledge has to be identified and updated by development or acquisition. To make sure that the knowledge is managed in the right direction, knowledge goals have to be defined and the knowledge or the result of knowledge management has to be evaluated. Realizing this knowledge management loop will implement a continuous update process of the knowledge basis. This loop signals the need for change concerning the knowledge and ensures that the knowledge basis is always updated. Within this loop, knowledge has to be identified and measured to compare the current knowledge situation with the desired situation. In this paper, we build a methodology to evaluate this knowledge concerning its need for the future. First, a literature study identifies existing approaches of knowledge evaluation. We analyse if these approaches are suitable for our research goals. Then, we combine two approaches from the literature and develop them to a methodology for measuring knowledge by comparing the needed usage and competitiveness of knowledge from the current and future knowledge situation. This methodology clusters knowledge by the degree of progress from the current to the future knowledge basis. Dependent on the classifications, we define how to deal with the knowledge to ensure an adequate knowledge structure in the future. In a single case study, we evaluate the methodology in a department of an engineer company and consider the statements of the involved persons to improve the methodology. At the end, we reflect upon the methodology and consider the strengths and weaknesses of applying the methodology in an organisation unit.

2. State of the art in knowledge evaluation

The most common approach of knowledge evaluation is the balanced scorecard [Kaplan and Norton 1992], which is a strategic tool to identify how the knowledge situation fits to the company's goals. Nevertheless, this evaluation method measures the benefit of the whole knowledge basis for the company's strategy and may be interested for investors but it is not possible to compare parts of the knowledge basis to each other. There are some other knowledge evaluation methodologies which deal

only with the holistic view on the knowledge structure [Oliver et al. 1996], [Housel and Nelson 2005], [Ahn et al. 2006], to compare the benefit of a company's knowledge to other assets of the company. However, these kinds of evaluation cannot be used to compare or to grade knowledge to each other. As we need a methodology to identify the useful or critical knowledge for the future scenario, these evaluation methodologies are not helpful.
A methodology for evaluating knowledge to each other is "Bloom's taxonomy" [Bloom and Krathwohl 1956]. This taxonomy from the educational science was made to evaluate learning objectives. It also can be used to evaluate how deep knowledge is available. Accordingly, a person can possess knowledge in six sequent levels: knowledge, comprehension, application, analysis, synthesis and evaluation. The higher the level is knowledge shall be acquired, the more efforts have to be spent to reach the level. One level of this taxonomy includes all lower levels. If a knowledge element is available on the level "application", it is also available on the levels "knowledge" and "comprehension" [Bloom and Krathwohl 1956].
Probst et al. introduced the competency matrix to order knowledge according the two dimensions competitiveness of knowledge assets and degree of knowledge usage [Probst et al. 2000]. Dependent on the position of knowledge in this matrix, Probst et al. distinguish between non-utilized competencies, unique competencies, non-essential competencies and fundamental competencies. For all of these competency categories, they suggest an activity, like outsourcing or larger usage. This is a useful approach for developing the knowledge. However, the assumptions and the activities are not consistent because the involving of a scenario or a future goal is missing. The suggested activities may be useful for a specific company and scenario but they are not universally applicable. This can be shown by an easy example: A design department of a light bulb company has a large competitiveness of knowledge in the design of the light bulb's glow wire and this knowledge has a high degree of usage. Nevertheless, the company plans to switch the light's technology from the conventional Edison's light bulb to the LED-technology, because the customer needs change to demand more LEDs than light bulbs. Therefore, the knowledge of designing light bulb's glow wire is not needed anymore. However, according to Probst et al. this knowledge is a unique competence and the usage has to be raised. In this case, the competence matrix did not express a reasonable activity for the knowledge. The competence matrix is not able to achieve this because the involvement of the knowledge's context and the temporal dimension is missing.
For an evaluation methodology, which identifies the useful knowledge for the desired knowledge structure in a company, none of the presented methodology is sufficient. The holistic view does not regard parts of the knowledge or knowledge elements but only knowledge in its entirety. Using Bloom's taxonomy, different knowledge can be compared to each other but this taxonomy alone is not sufficient to identify knowledge, which is useful for the future. It is not clear which knowledge should be available in which level. Therefore, rating knowledge with this taxonomy only is not enough. The competence matrix of Probst et al. achieve some of the requirements for comparing knowledge specifically, which other evaluation methods do not. However, this competence matrix has still some weak points. The matrix does not involve the context of the knowledge, what the knowledge is needed for, but points out some activities. The activities suggested by Probst et al. are not always suitable as we explained by taking the example of the light bulb company. We claim that suitable activities or reactions can only found by involving the context of knowledge, as knowledge in companies is not an end in itself. Furthermore, the temporal dimension is missing in the competence matrix of Probst et al. Using this dimension, the tendency of knowledge in the company can be shown to illustrate the necessary development of knowledge.
We propose to involve scenario techniques into this competence matrix. This means that current knowledge will be illustrated in this matrix and knowledge, which is needed according to the scenarios for the company. Therefore, the competence matrix will include the actual knowledge and the desired knowledge. With this scenario-based knowledge, the context of knowledge will be involved into this matrix, as the desired knowledge is dependent on the scenarios the company wants to meet in the future. Moreover, the desired knowledge structure describes the knowledge, which is wanted for the future, therefore the competence matrix is also extended by a temporal dimension.

3. Methodology for knowledge evaluation

For our methodology, we will first define what we see as a knowledge structure. Then, we will describe Bloom's taxonomy which we use to rate the depth of knowledge. After that, the approach of using scenario techniques for knowledge maps is described which we use in our approach. Finally, we propose our approach of building a competence matrix by adjusting the competence matrix of Probst et al. and including knowledge vectors, which characterize the knowledge.

3.1 Knowledge structure

Knowledge can be seen as a complex structure, which consists of elements and relations between these elements. According to Eppler, knowledge can be divided in elements and such a knowledge element stands for a special range of thematic knowledge [Eppler 2001]. Other elements than knowledge elements can affect the knowledge structure. For example, the people or documents, which possess the knowledge or the tasks, which the knowledge is needed for, can be seen as a part of the knowledge structure. We use the approach of knowledge structure from Wickel et al. who use the three domains tasks, employees and knowledge to describe the knowledge structure [Wickel et al. 2013]. This kind of knowledge structure can be illustrated in a matrix-based knowledge map. A generic visualization of such a knowledge map is shown in Figure 1.

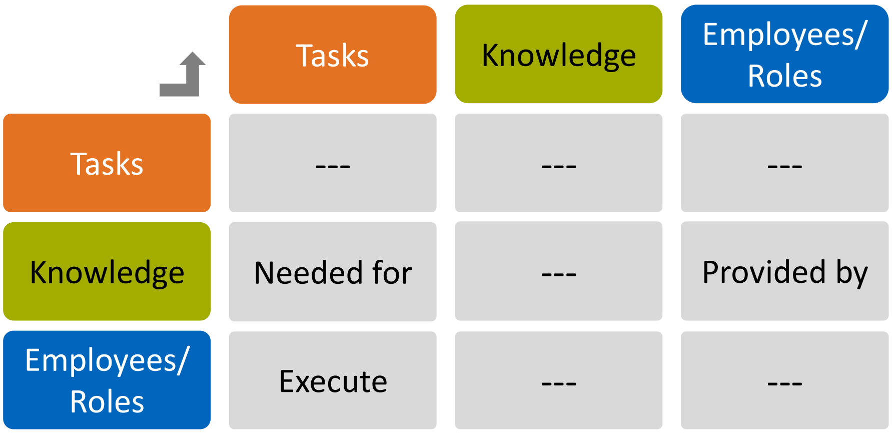

Figure 1. Matrix-based knowledge map

Between the elements of the three domains are the following relations: Employees perform tasks, employees possess knowledge, and knowledge is needed to perform tasks. For the elicitation of this knowledge map, employees are interviewed for their tasks and the knowledge they need to perform these tasks. Interviewing all employees of a department or a company results in one knowledge matrix for every employee. All these matrices are added and summarized to one overarching knowledge map for the whole organizational unit. This matrix shows who employee performs which task and needs which knowledge for this, so it shows the current knowledge structure of the regarded organizational unit.

3.2 Evaluating the depth of knowledge

To extend the knowledge map of the current knowledge structure, the knowledge elements can be rated by Bloom's taxonomy. Crooks took up this taxonomy and claimed that six levels are too much for practical application [Crooks 1988]. Based on this finding and on [Bloom and Krathwohl 1956], Schenkl et al. defined a scale for evaluating the depth of knowledge and introduced the three levels "retain knowledge", "comprehension" and "problem solving" which summarize the six levels of Bloom to three levels. For our application, this approach of three levels is reasonable because we let the employees rate the knowledge. Since we built our methodology for engineer context, the interviewed employees have engineer background and they might not know Bloom's taxonomy. The usage of only three levels is clearer for engineers and provides results that are more appropriate. The taxonomy of Schenkl et al. we use for our approach is shown in Table 1.

Table 1. Scale for depth of knowledge, according to Schenkl et al. [2014]

	Definition
Retain Knowledge	"The first level describes the recalling and recognition of facts, patterns, processes, classification, criteria or categories. This level is characterized by its passive knowing and a limited ability to describe it."
Comprehension	"The second level embraces comprehension and application. Comprehension is the ability to recognize simple correlations as well as the independent ability to explain. Application is the ability to apply knowledge in new situations."
Problem Solving	"This level comprises analysis, synthesis and evaluation. Analysis is the ability to decompose complex problems into fundamental elements and to recognize the relations between these elements. Synthesis is the ability to combine fundamental elements to a new system by developing a new structure. Evaluation is the ability to judge including internal and external validity based on a set of criteria."

We use this knowledge rating for two different perspectives. The first perspective is to rate how deep employees are skilled at a knowledge element (*employee-oriented*). This describes the actual and real situation, as the current situation is in the company. The second perspective is to rate the deepness of knowledge, which is required to perform a task (*task-oriented*). This depicts the desired situation: How deep should employees be equipped with knowledge.

3.3 Scenario knowledge map

For the definition of the scenarios of the organizational unit and the creation of the knowledge map for the desired knowledge structure, we use the approach of Schmidt et al. According to this paper, scenarios for the regarded organization are defined and dependent on these scenarios, a knowledge map is built which shows the desired status of the knowledge structure in the future [Schmidt et al. 2013]. Using this approach, the knowledge map of the desired knowledge structure is built. Additional to this map, we let the managers of the organizational unit, who built this knowledge map, rate the depth of knowledge for the future knowledge situation. For this, we chose the task-oriented rating. Which kind of rating to choose for what kind of knowledge map is described in Table 2. We basically have two options of rating: The employee-oriented rating which is the rating of the actual situation and the task-oriented rating which is the rating of the desired situation. Towards these two options are the options of the temporal property of the knowledge map. A knowledge map can describe the current situation or the future situation. As the current knowledge map describes the actual situation of the knowledge structure, we chose the employee-oriented rating to illustrate the situation of the knowledge structure how it is. For the current situation, the task-oriented rating might be useful if we want to know how the knowledge is supposed to be available at present. This can be used to identify weaknesses in the current knowledge structure, if an employee cannot perform a task adequate because he does not possess the knowledge in the required depth. For the future knowledge map, we chose the task-oriented rating because we see the future knowledge map as a concretization of the scenarios, which describe the desired status of the regarded organizational unit. The employee-oriented rating for the future situation might be reasonable if the scenario does not describe the wished situation in future but the resulting knowledge structure if the employees do not change their knowledge.

Table 2. Rating for depth of knowledge

	Current situation	Future situation
Employee-oriented rating	How is the knowledge structure today?	How is the knowledge structure in the future?
Task-oriented rating	How should the knowledge structure be today?	How should the knowledge structure be in the future?

3.4 Adjusting the competence matrix

In chapter 2, we already indicated that the competency matrix by Probst et al. still has some weak points, for instance the lack of temporal dimension and the lack of involving knowledge goals. For this reason, we improve the competency matrix. We remove the activities suggested by Probst et al. because the question what do to with knowledge to raise the company's efficiency cannot answered without involving the scenarios. Secondly, we change the terms for the knowledge categories, which are dependent on the competitiveness of knowledge assets and the degree of knowledge usage. Our model of the competence matrix is shown in Figure 2.

Knowledge with a small usage and a low competitiveness is characterized as "non-essential competencies". We changed it to "occasional basics" because these knowledge can be also essential for the company. Knowledge, which is not often used and has a low level of competitiveness, may be important for the company if this knowledge will needed be in the future more often. Therefore, we decided to use a more neutral term for this kind of knowledge. We use the term "peripheral competencies" for "non-utilized competencies" because this knowledge is utilized but it is not often utilized and the term "peripheral" describes this less utilization better. We accept the two other terms "unique competences" and "fundamental competences" for our competence matrix, which is shown in Figure 2.

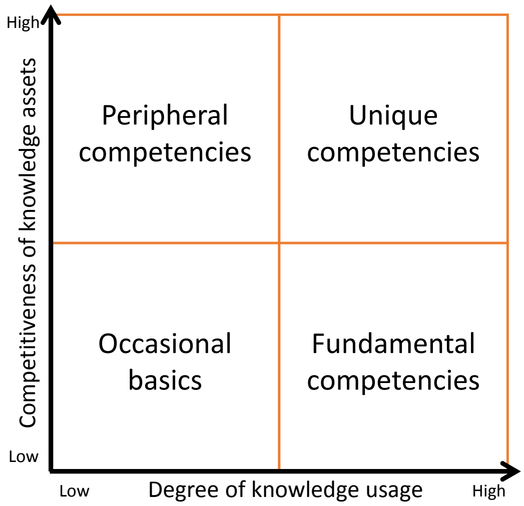

Figure 2. Adjusted competence matrix

Now, we want to include the knowledge elements from the knowledge map to this competence matrix. For this purpose, we have to define the competitiveness of knowledge assets and the degree of knowledge usage. The degree centrality of a knowledge element in a knowledge map describes the number of tasks the knowledge element is used for. If we assume that all tasks have the same granularity and the frequency of the task's executions is similar, this degree centrality can be used for the degree of knowledge usage. If the granularity of tasks and the number of execution of the tasks are different, other parameters can be additionally factored in this number. Examples for these parameters are number of execution of tasks, time slice of tasks, number of employees who perform a task, number of employees who possess a knowledge element.

The calculation of the knowledge competitiveness is more challenging because the competitiveness depends on many parameters. The competitiveness is exemplary affected by the depth of knowledge currently available in the organization, the depth of knowledge currently available for competitors or the relevance of knowledge for future. These are just some exemplary parameters and there are too many impacts to define this competitiveness exactly. Within this paper, we only factor in the depth of knowledge currently available in the organization. This parameter correlates with the competitiveness of knowledge. If a company wants to have a competitive knowledge, the knowledge has to be developed and deepened within the company, which corresponds to raise the knowledge to a higher level. To show the difference to the competitiveness we change the ordinate of our competency matrix to depth of knowledge.

3.5 Knowledge vectors in the competence matrix

After this definition, we insert the knowledge elements of the knowledge maps into our competency matrix and categorize the knowledge elements into the terms we defined in Figure 2. As two knowledge maps are available, the map of the actual and the desired knowledge structure, two related competency matrices can be built. Furthermore, both matrices can be overlaid to demonstrate the evolution of knowledge. This is exemplary shown in Figure 3 where this evolution is illustrated by a vector.

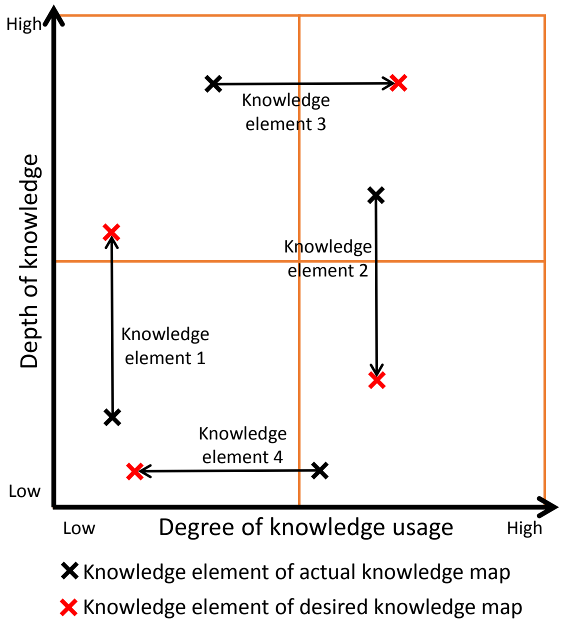

Figure 3. Knowledge vectors in the competence matrix

Dependent on the properties of the vectors, appropriate statements can be made. The length of the vector correlates with the amount of change, which will be necessary for the regarded knowledge element. Knowledge elements with short vectors do not have to be modified a lot, they are not critical regarding the changes in the company. The longer the vector the more the knowledge elements have to be regarded and treated. Another property of the vector is the direction. The horizontal amount of the vector describes the change in the usage of the knowledge element. The vertical amount describes the change in the depth of knowledge. Accordingly, knowledge elements of vectors pointing right and upwards need some efforts to belong to the desired status. Against this, knowledge elements of vectors pointing left and downwards are not critical regarding the changes because they are in the current situation in a more frequent and deeper usage. We define four initial vectors dependent on the direction. Their interpretations and recommended reactions for related knowledge elements are depicted in Table 3.

Table 3. Initial vectors and their interpretations

	In Figure 3	Interpretation	Reaction
Up vector	Knowledge element 1	No change in the usage, raise of the depth of knowledge necessary	Develop the company for more depth of knowledge
Down vector	Knowledge element 2	Usage constant, depth of knowledge negligible	Avoid drain of knowledge
Right vector	Knowledge element 3	Depth of knowledge constant, more usage	Increase the availability of the knowledge element in the company
Left vector	Knowledge element 4	Depth of knowledge constant, less usage	Avoid too much drain of knowledge

Using this methodology, we involved the context of knowledge and a temporal dimension. By including the desired knowledge structure into the competence matrix, we factored in the objective the knowledge will be needed for because the desired knowledge structure describes the scenarios where the company wants to be in the future.

4. Case Study

For the evaluation, we applied the methodology in a department of an engineer company, which provides product service systems. The knowledge map of the current knowledge structure was built by interviewing seven employees of the service department. Some of them were mechanical engineers and some of them were electrical engineers. For the evaluation of the depth of knowledge, two lead employees were selected who are more experienced than the other ones. Furthermore, they declared time slices for all tasks. Based on this knowledge map, two persons of the department's management designed a scenario for the department to increase the customer connectivity. This should be accomplished by increasing the service for the customers. Dependent on this scenario and the current knowledge map, the management built the knowledge map of the desired knowledge structure in five years. After that, they evaluated the depth of knowledge for the knowledge elements which are needed for the future and set the time slices for the tasks. With this data, we were able to build the competence matrix for the current and future knowledge map. For the degree of knowledge usage, we calculated the degree centrality of every knowledge element and weighted them by the temporal time slices of the tasks, the knowledge elements are needed for. We did not factor in the number of employees who perform a task or who possess a knowledge element because the knowledge elements and tasks are evenly distributed on the employees. In other words, the range of tasks and knowledge is very similar for all employees.

The tasks' time slices of the current and future knowledge maps are shown in Figure 4. The differences of the time slices from current to future knowledge map are partly very high, the time slice of task category 4 is almost three times higher in the future knowledge map than in the current knowledge map. This will be have an effect on the differences at the competence matrices concerning the knowledge usage. Some of the knowledge elements will great changes in the degree of knowledge usage although they are not needed for more or less tasks, only the differences in the time slices are the reason.

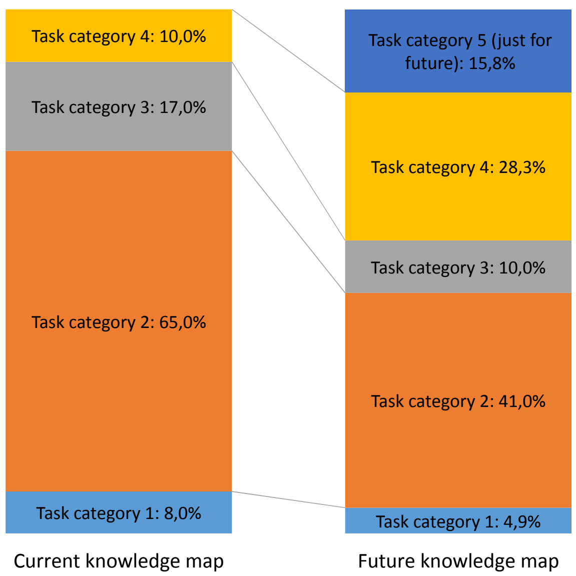

Figure 4. Time slices of task categories of the current and future knowledge map

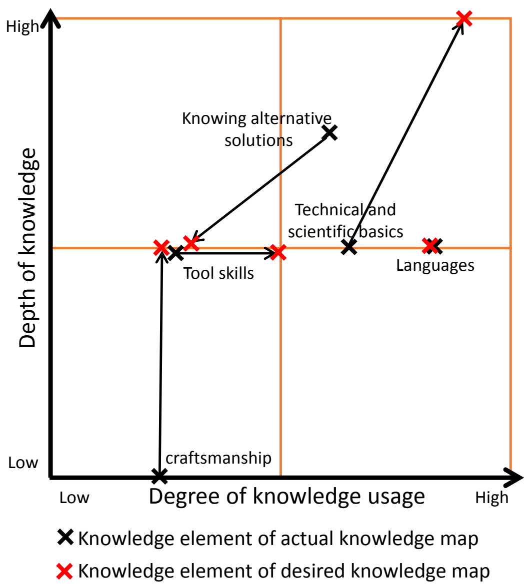

Figure 5. Knowledge vectors of current and future knowledge map

Figure 5 shows the competence matrix for a number of knowledge elements in their state in the current and future knowledge maps. In the average, knowledge elements progress to a higher level of knowledge and to a higher degree of usage. The mean delta of the degree of knowledge usage was +0.13 (on a scale from one to three) and the mean delta of the depth of knowledge was +0.58 (on a scale from one to three). The change of the knowledge usage is relatively small, because most of relations between knowledge and tasks from the current knowledge map were transferred to the future knowledge map. The delta is only generated by connecting to new tasks of the future knowledge map and by the changes in the tasks' time slices. The theoretical highest possible amount of the delta of the depth of knowledge is 2.0, therefore 0.58 is a relatively high amount. One reason for this is that the current knowledge map was built by employees of the department and the future knowledge map was built by the management of the department. Apparently, the management tent to expect more from their employees than their performance. Furthermore, one manager pointed out that one of the selected employees tents to underrate his own performance. Still, the management admitted that some knowledge elements have to be available in a higher depth of knowledge. We discussed all changes in the competence matrix with the management and the employees and they agreed with the results. According to their statements, the changes in the competence matrix are consistent results and for all of them amendments are necessary. To identify the knowledge elements, which are most critical regarding the requirement for amendment we conduct an ABC-Analysis and selected 10% of the knowledge elements with the highest amounts of change. The amount of change is the length of the vector of change in the competence matrix which is calculated according to equation 1 based on the Euclidean norm.

$$total\ amount\ of\ change = \sqrt{(depth\ of\ knowledge)^2 + (degree\ of\ knowledge\ usage)^2} \quad (1)$$

Using this, we were able to present the most critical knowledge elements of the department to sensitize the management and employees for the crucial requirement for amendment.

The conduction of the case study revealed the limitations and advantages of the methodology, which are described in the conclusion. Furthermore, the applicability of the methodology was shown. According to the requirements of the methodology for the evaluation of knowledge, the basic elements for the evaluation were built by creating the knowledge map of the current and future knowledge situation. We could make the employers and employees aware of the difference between current and desired knowledge structure and we identified the most critical knowledge elements regarding the required change.

5. Conclusion

We built a methodology to evaluate company's knowledge concerning the suitability for the company's scenario. For this, we extended the competence matrix developed by Probst et al. by involving the context of knowledge and a temporal dimension. This adapted competence matrix makes it possible to quantify the needed changes to reach the desired knowledge structure and to identify knowledge which is critical in terms of the requirement for amendment.

5.1 Limitations

The methodology was evaluated successfully in a case study but the analysis of the results pointed out some weak points of the methodology. As the changes of the depth of knowledge and the knowledge usage of the knowledge elements are essential for the results, the choice of the people who build the current and the future knowledge map is essential for the quality of the results. Since different persons built those knowledge maps in the case study, some of the differences between the current and future knowledge map may be caused by reason of the different individual views. As we did in the case study, employees of the department should build the current knowledge map and the department management should build the future knowledge map. Employees tent to describe the real situation they see in their daily routine, they are geared for describing the actual situation and the employee-oriented rating (see Table 1). As the department management is not as much involved into the daily routine as the employees are, the management is geared for describing the desired situation and the task-oriented rating (see Table 1).

The results' quality of rating the depth of knowledge has to be considered critically. Especially the employee-oriented rating where employees rate their own depth of knowledge may be problematic. According to Harris and Schaubroeck, the self-assessment of performance differs widely from external assessment by peers or supervisors [Harris and Schaubroeck 1988]. Transferred to rating the depth of knowledge, this difference has to be regarded in the analysis of the results. The Dunning-Kruger effect describes the issue that employees may overestimate and some employees may underestimate their own competences. Dunning et al. claimed that people could not estimate their own competences because they do not have enough information and they sustain information for an adequate evaluation [Dunning et al. 2004]. The results of a survey conducted by Zenger correspond to this effect. In this survey, engineers of two companies assess their performance relative to their peers and 36 percent placed their performance in the top five percent in the company. Only one respondent of in total 714 responded employees placed his or her performance below the average [Zenger 1992].

In 3.4, we assumed the depth of knowledge for the competitiveness of knowledge assets. This is just a rough assumption and to rate the competitiveness of knowledge, more than just the depth of knowledge has to be factored in. Especially the situation of competitors regarding this knowledge has to be involved. There is still need for research to evaluate knowledge regarding the competitiveness.

5.2 Benefits and further work

The differences of current and future knowledge map, caused by different people who built the knowledge maps, includes also a benefit of this approach. Using the employees for the current and the management for the future knowledge map reveals the different views of those persons. This visualization is one benefit of the methodology because it is very helpful for planning the future of the department to clarify the different points of view on the department's tasks. The participants of the case study also confirmed that they have not been aware of this gap between the employees' and management's perspective.

Compared to the activities suggested in the competence matrix of Probst et al., our results are not as concrete as the activities developed by Probst et al. We were able to propose the reactions dependent on the vectors in the competence matrix, mentioned in Table 2. These reactions are more abstract and may seem to be not as useful as the activities suggested by Probst et al. But the advantage of these abstract reactions is that they are universally applicable and not referred to special cases. In this area more concrete reactions can be found by a more specific analysis of the knowledge elements in the case study. Especially the belonging of knowledge to one of the four characteristic knowledge areas, "occasional basics", "peripheral competencies", "unique competencies", and "fundamental competencies", should be considered. If a knowledge element change between the characteristic knowledge areas from the current knowledge structure to the desired, some statements can be derived from this change.

A benefit not considered yet of applying this methodology in an organizational unit is the effect on the employees. As they reflect their tasks and knowledge they fulfil and need for their work, employees become more aware of their range of tasks and duties within the organization. They realize the borders and interfaces of their task area between and to other employees, which can improve the efficiency of the organization. Levitt and March point out that clear responsibilities in organizations simplify to retrieve routines and to learn [Levitt and March 1988]. Furthermore, the allocation of clear responsibilities is seen as a success factor for projects [Young 2003], [Karlsen et al. 2006].

References

Ahn, J.-H., Lee, D.-J., Lee, S.-Y., "Balancing Business Performance and Knowledge Performance of New Product Development: Lessons from ITS Industry", Long Range Planning, Vol. 39, No. 5, 2006, pp. 525-542.

Bloom, B. S., Krathwohl, D. R., "Taxonomy of Educational Objectives Book 1: Cognitive Domain", Longmans Green, New York, 1956.

Crooks, T. J., "The Impact of Classroom Evaluation Practices on Students", Review of Educational Research, Vol. 58, No. 4, 1988, pp. 438-481.

Dunning, D., Heath, C., Suls, J. M., "Flawed Self-Assessment - Implications for Health, Education, and the Workplace", Psychological science in the public interest, Vol. 5, No. 3, 2004, pp. 69-106.
Eppler, M. J., "Making knowledge visible through intranet knowledge maps: concepts, elements, cases", 34th Hawaii International Conference on System Sciences, 2001, pp. 4-9.
Harris, M. M., Schaubroeck, J., "A Meta-Analysis of Self-Supervisor, Self-Peer, and Peer-Supervisor Ratings", Personnel Psychology, Vol. 41, No. 1, 1988, pp. 43-62.
Housel, T. J., Nelson, S., "Knowledge Valuation Analysis: Applications for Organizational Intellectual Capital", Journal of Intellectual Capital, Vol. 6, No. 4, 2005, pp. 544-557.
Kaplan, R. S., Norton, D. P., "The Balanced Scorecard – Measures That Drive Performance", Harvard Business Review, Vol. 70, No. 1, 1992, pp. 71-79.
Karlsen, J. T., Andersen, J., Birkely, L. S., Odegard, E., "An empirical study of critical success factors in IT projects", International Journal of Management and Enterprise Development, Vol. 3, No. 4, 2006, pp. 297-311.
Levitt, B., March, J. G., "Organizational Learning", Annual Review of Sociology, Vol. 14, No. 1, 1988, pp. 319-338.
Oliver, D., Marchand, D. A., Roos, J., "Skandia Assurance and Financial Services: Measuring and visualizing intellectual capital", 1996.
Probst, G., Raub, S., Romhardt, K., "Managing Knowledge Building Blocks for Success", John Wiley & Sons, Ltd, New York, 2000.
Schenkl, S. A., Schmidt, D. M., Schockenhoff, D., Maurer, M., "Knowledge Evaluation for PSS Providers", 6th CIRP Conference on Industrial Product-Service Systems, 2014.
Schmidt, D. M., Schenkl, S. A., Wickel, M. C., v. Saucken, C., Maurer, M., "Multiple-Domain Matrices and Knowledge Maps for Visualizing Knowledge-Driven Scenarios", 15th International Dependency and Structure Modelling Conference, DSM 2013, Scheurmann, E., Maurer, M., Schmidt, D., Lindemann, U. (Eds.), Melbourne, Australia, 2013, pp. 55-62.
Wickel, M., Schenkl, S. A., Schmidt, D. M., Hense, J., Mandl, H., Maurer, M., "Knowledge structure maps based on Multiple Domain Matrices", InImpact: The Journal of Innovation Impact, Vol. 5, 2013, pp. 5-16.
Young, T. L., "The handbook of project management", Kogan Page, London, 2003.
Zenger, T. R., "Why Do Employers Only Reward Extreme Performance? Examining the Relationships among Performance, Pay, and Turnover", Administrative Science Quarterly, Vol. 37, No. 2, 1992, pp. 198-219.

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