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A COMPETENCE MANAGEMENT METHODOLOGY FOR VIRTUAL TEAMS – A SYSTEMIC APPROACH TO SUPPORT INNOVATION PROCESSES IN SME'S

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1. Introduction

Virtual instruments and tools are future trends in Engineering which are due to the growing complexity of engineering tasks. Over the last few years, international cooperation not only takes place in production but to an increasing degree also in the field of product development. Global competition, reengineered product life cycles, mass customisation and strong collaborations on the international market are, according to Grenier and Metes, some of the trends that drive currently to organisational changes and a rising value of Virtual teams to generate innovation [Grenier and Metes 1995]. Also Huanga et al. highlights that in our time of reducing pre-financing costs of product and service development and working under timely, shortening, time-to-market conditions virtual teams seem to be a decisive factor to evolve innovation [Huanga et al. 2002]. Although virtual collaborative environments and platforms are getting more and more popular in various domains, Horvarth and Tobin point out that until now only little research has been done on the network of influencing factors on the effectiveness or the requirements of the user [Horvarth and Tobin 2001].

The focus of this work is set in Small and Medium-sized Enterprises (SMEs) as the open-world economy is facing the challenging need for creativity and innovation by SMEs, that are often faced with the difficulty of satisfying the requirements of the market. Strategic alliances between networked enterprises are needed for opportunity building, idea creation and product design and development to tackle the necessity of specialized and expensive high-tech equipment, software tools and simulators. These are done in short-term projects as well as the complexity of the open-world economy. But what are the critical terms and conditions for a system that takes these different aspects into account?

Due to the systemic approach of the functional analysis that is the basis of our study, our paper meet the demand of a methodology of competence management to create competitive virtual teams for supporting innovation processes in SMEs and aims to give a structure to this complexity.

2. Objectives of our study

The changing nature of teams has brought on a need to identify the competencies that are necessary to work effectively in a virtual team environment to raise innovation. According to Horvarth and Tobin, existing literature is mainly based on collocated teams, but empirically-based prescriptions, guidelines and specifications for virtual team competencies are often missing [Horvarth and Tobin 2001].

Our systemic approach of the functional analysis responds to the need of a system of competence management methodology to create competitive virtual teams for supporting innovation processes in SMEs.

We intend to give a clear picture of this system, to take different ideas and important central features into account and to also master the complexity of it. The formulation of functions in our systemic approach will help us to describe the optimum behaviour of the system and its terms of usability.
Building on this systemic analysis, we investigate new perspectives in order to obtain new research directions. This will make it possible for us to give guidelines and recommendations for further research, as well as to improve critically-developed research questions that can guide future inquiries and could help to implement a system like ours in industry.

3. State of the Art

The following paragraph examines policy issues and defines concepts of virtual teams, competences, innovation and their interfaces. At the same time, it gives a first overview of diverse aspects that play a decisive role in our system of competence management to create competitive virtual teams for supporting innovation processes in SMEs.
Today’s economic prosperity depends on generating new knowledge, innovation and technological progress. Striving for worldwide competitiveness requires access to worldwide communication, as prospective partners and customers are spread out over countries and even continents. It is increasingly important that working results return quickly so that clients’ needs can be responded to quickly and capture a strategic market position for new product development. Working power has to be available just when it is needed to rapidly complete required tasks by having a fast access to all necessary resources such as competences or knowledge, regardless of where they are situated.
In this context, virtual teams and virtuality are seen nowadays as a continuum, which means that many teams in organisations today are characterized by dimensions of virtuality, as this is the only way to collaborate. According to Griffith et al., virtual teams have the virtual aspect and the same characteristics as other teams, but this narrow difference interferes with a significant diversity of innovation processes in organisations [Griffith et al. 2003]. He defines virtual teams as groups of individuals who work together in different locations at interdependent tasks. They share responsibility for outcomes and rely on technology for much of their communication to counteract their geographic dispersion [Griffith et al. 2003].
Their raising importance has evoked a demand to identify the competencies needed to work effectively in a virtual team environment to create innovation. Competence is seen as the basis of competitiveness, it enables a company to offer products and valued services to customers and to innovatively generate new products and services. Sustained competitiveness requires flexibility in organisational processes, dynamic access to critical competences, additional resources, knowledge about the customers and their international context. Individuals who are working in virtual teams must be equipped with spanning competences that provide a basis for virtual team building, learning and creativity, and finally innovation. The quality of interaction between people is one of the most important success factors to facilitate changes and to foster innovation.
According to Kleef and Roome there are four kinds of main capabilities in regard to innovation in highly diverse networks, platforms or virtual teams. These include the capabilities to create and maintain trust, to solve problems collectively in diverse teams, networking capabilities and the ability to form and maintain strong relationships [Kleef and Roome 2007]. Capabilities of individual team members, combined with each other and connected through structures and routines, are the building blocks of competence. Competence, therefore, includes the organisation of work, the involvement of team members, the commitment to work and communicate across boundaries within the organisation, and the delivery of value to clients and other stakeholders.
Competence is defined according to Prahalad and Hamel as the learning process within the organization about how to coordinate diverse production skills and how to integrate technologies [Prahalad and Hamel 1990].
Through the capacities and competences of the stakeholders involved, innovation has a key role in our system providing the development of products and services.
According to Galbraith, innovation, with the meaning of doing something new or something known in a different way, is seen as the process of discovery and development that creates new products, production processes, organizations, technologies, institutional and systemic arrangements [Galbraith

1996]. Innovation is not necessarily connated to problem solving, but it is usually related to improving competitiveness and has an economic significance, as well as often being actuated by technology. He emphasises that innovation usually combines technological aspects like product or process innovation with organisational aspects such as social innovation which requires planned improvements on an individual level as well on interpersonal level [Whipp and Clark 1986].

This mixture highlights why it is important for understanding innovation processes to take the competences of stakeholders into account who support and influence innovation.

We have put the focus of this work on SMEs because in many cases, the creation of new scientific knowledge takes place in public research institutions whereas the implementation of technological innovations in form of new products, services and production processes happens in the private enterprise sector of an economy. Thus, SMEs play a vital role for growth and employment in Europe. However, according to several analyses of the European Commission, Europe, in comparison to its main competitors, the US and Japan, performs excellently in public scientific research, but lags behind in business innovation and R&D. Europe's weakness, also known as the "European paradox", lies pursuant to an Observatory of European SMEs in 2002. The findings were that Europe had an insufficient ability to transform results of technological research into innovations and competitive advantages based on a lack of skilled labour (20%), access to finance (13%), administrative regulations (12%), and infrastructure (6%) [Observatory of European SMEs 2002].

Our systemic approach of the functional analysis aims to combine these different concepts, to draw out interfaces and to structure the complexity according to importance. By considering critical terms and conditions of different concepts that are crucial aspects for our system of a methodology of competence management for virtual team building we intend to break new ground. The systemic approach of the functional analysis offers a different way to look to this challenge.

4. Method

For understanding and mastering the complexity of our system of "a compentence management methodology for virtual team building to support innovation processes in SMEs" we need a holistic approach which helps to identify needs and requirements, shows interrelations and leads to the establishment of sustainable research results.

We decided to use the functional analysis that is referring to Snodgrass often chosen as an instrument of new product development processes because its power lies in its ability to take different ideas and apply a united symbolism and theory to deal with the important central features of the problem [Snodgrass1986]. It helps to gain a clear picture about functionalities and usability of a product or a service and assists in identifying main actors in the field. Referring to the APTE® formalism for conducting a Value Analysis and based on "value engineering", it takes into consideration the various points of view of different research domains as well as the environmental aspects influencing the system [Apte 2000]. The functional analysis employs the most powerful problem solving techniques devised of both, the Value Analysis and the value engineering. It combines the divergent and convergent techniques of both to arrive at the best and most possible solutions.The proposed method follows the steps of figure 1, which will be used as a guideline in this paper.

5. Results

5.1 Validation of the system

To validate the interest of our system we used in the first step the "horned animal" which has its roots in the APTE® formalism of the Value Analysis method. APTE® is a method of Value Analysis that introduces two additional diagrams: the "horned animal" and the "octopus" which will be used in the next step [Apte 2000]. The "horned animal"which is seen in figure 2 allows the formalisation of a system by discussing questions like: a) who takes advantage of the system? b) what does the system act on? and c) what is the system's purpose? The technique of the horned animal is used as a first approach to determine the scope of the system and to understand the opportunities and limitations of its framework. It is crucial to know directly in this stage about the target group, the reason for its existence or its intention. If it was not possible to answer these questions, the sytem wouldn't have the right to exist

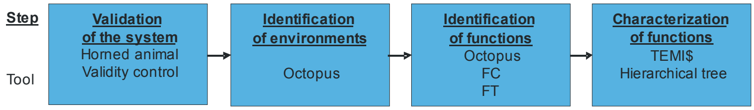

Figure 1. Steps and tools of the functional analysis

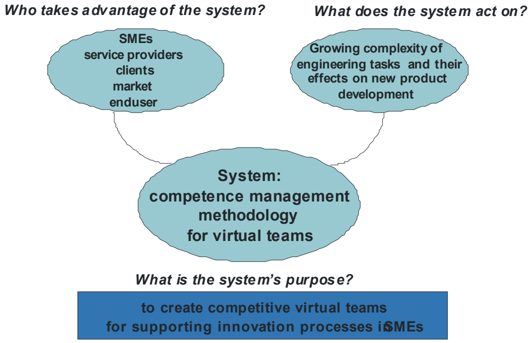

Figure 2. Horned animal according to the system

In a further step of the system's validation we made a validity control in order to conclude on the necessity or not to carry out the study about the system, whose results were satisfying.
The validity control, which is shown as an extract in figure 3 aims at the determination of three aspects: the cause of the system (because), the objectives it aims for (for), and the risks of evolution or disappearance of the need (risk).

Validity control of the system		
Which are the reasons for the system's existence?	**"because"**	▪ SMEs need to capture a strategic market position for new product development ▪ virtual teams could be more effective if we moved ahead in the field of competence management ▪ competencies have to be available just when it is needed to rapidly complete required tasks ▪ there is a need of access to new and larger markets, know-how and technology
Which are the objectives and aims of the system?	**"for"**	▪ to provide a fast access of all necessary resources (competences, knowledge), irrespective of where they are situated ▪ to enable SMEs to develop more sophisticated and innovative products and services ▪ to provide a methodology allowing to match requirements with coherent competences
For which reasons the system could become useless and disappear?	**"risks"**	▪ development of new tools, which make web-based communication systems needless

Figure 3. Extract of validity control of the system

5.2 Identification of environments

The so-called method of the "octopus" identifies environments that act with the system to get a holistic overview of the system's framework [Apte 2000].
In general, this step of the functional analysis is conducted within a brainstorming process in multi-disciplinary teams. It is a relevant instrument to support innovation processes within a company as it helps to establish a common view on a new product or service and the identification of opportunities that have been neglected thus far. To give consideration to this demand of multidisciplinarity we analysed about 100 articles of different sciences that are dealing with the topic of "virtual team

building" regarding their keywords to define our environments. During this process it is essential to be as open-minded and inclusive as possible.
According to our system we defined the following environments which are seen in figure 4. In order to get a structure in the complexity of the analysed environments we clustered them. Clusters represent the main elements that have been identified. Sub-clusters were built whenever similar specifications were seen and family groups could be built.

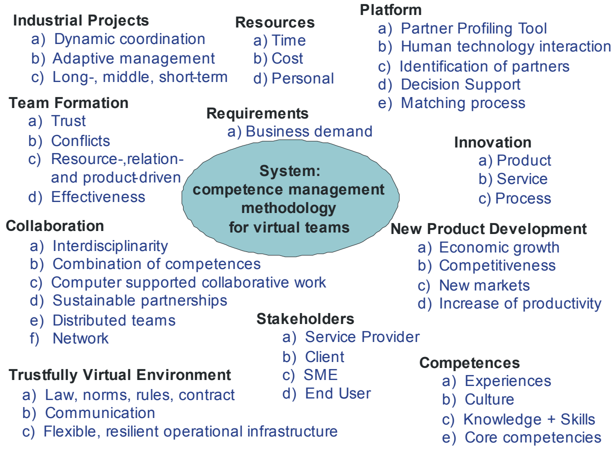

Figure 4. Clustered environments according to the system

We identified 11 main environments with 40 sub-environments included in the sub-clusters which are self-explanatory. Even if we tried to be as inclusive as possible, we are aware that the list of our environments is not complete.
One of our system's most important environments is represented by our **stakeholders**. It is composed of SMEs, clients, service providers and end users. Even if SMEs build a separate sub-cluster, they could be either client, service provider or end user all at once. All of them have to be considered as crucial players in our system because they define the **requirements** in the process of **new product development**, another main environment whose existence is the basis of the functioning of the system. These requirements shall be pursued in collaborative long, middle or short-term **industrial projects** to share **resources** like time, costs or personnel in a **trustworthy virtual environment**. Supported by a **platform** that highlights the human-technology interaction and should be more than only a partner profiling tool which matches competences with requirements, **team formation** gets more focused and presents another cluster. Only the right combination of **competences** assure an effective **collaboration** to create **innovation**.

5.3 Identification of functions

The second step of the method of octopus is important in order to describe the elements of the system's environment. In this stage the functional analysis aims at the formulation of functions, describing the optimum behaviour of the system and its terms of usability. There are two kinds of functions: the transfer functions (FT) which are at least two different environments that interact by the means of the system, and the constraint functions (FC) which are generated by only one environment and that the system has to respect absolutely [Apte 2000].
Each component of an open and living system interacts constantly with its environment by means of information and matter-energy exchanges. This means that it is not enough to take only the system itself into account, but the whole interaction between the system and the environment in which it is acting to assure consideration of the whole system.
Some of the detected FT functions during the application of the octopus method on our system are shown in Figure 5.

It is self-evident that the sub-clusters have not been neglected in this process but are not listed in order to facilitate the visuality. Sub-clusters can interact with other sub-clusters or main clusters in the same way as main clusters do.
Through this technique of establishing interfaces between the environments, we have identified 243 transfer functions and 38 constraint functions. In a collaborative negotiation process we have defined key functions that represent main aspects of the system and help us to determine additional factors. An excerpt of those key functions that will be considered for further analysis is shown in the following listing.

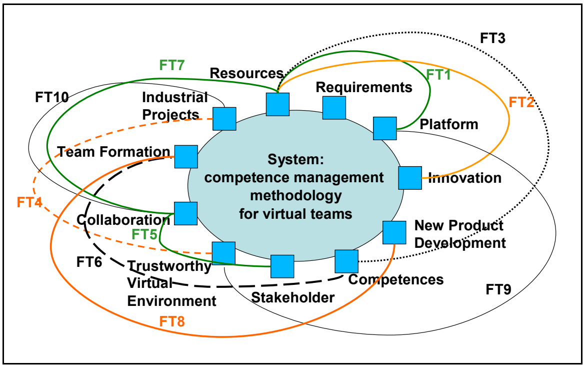

Figure 5. Extract of functions according to the identified environments

FT23 The system should provide an **adaptive management** of **industrial projects** that is able to react to different **requirements** in a **human technology interaction**.

FT48 The system should provide the possibility to use a **platform** for **decision support** in the process of **new product development** that facilitates the sharing of **resources** in a **trustworthy virtual environment.**

FT98 The system should promise to develop **long, middle and short-term projects** to attain **innovation** and increase the **competitiveness** and **productivity** of **SMEs.**

FT118 The system should make **knowledge** and **competences** usable for **SMEs** concerning the specific **requirements** of **new product development**.

FT216 The system should provide an unerring **combination of competences** to assure a **network** of **sustainable partnerships** in the process of **new product development**.

FC2 The system should reconstruct itself through **projects** in a **trustworthy virtual environment.**

FC26 The system should provide an efficient and effective identification of required **resources**.

5.4 Characterization of functions

To draw more profound conclusions, the identified functions have been analysed in a further step with a method called TEMI$ which stands for **T**ime, **E**nergie, **M**aterial, **I**nformation and Cost**$**. This method teaches us how to obtain concrete information about interdependences to make concrete statements about our system. Figure 6 is an example of this kind of analysis.
Extract of further conclusions that we identified through the analysis of TEMI$:

- Virtual environments should be optimised and not only focus on the technology as they face the same challenges as face-to-face teams in addition to others (other what, other teams?). These include as the limitations of technology, cultural differences or the question of trust. (-> FT23)
- Working in virtual teams establishes a basis which allows a strategic market position to be captured for new product development as well as building international virtual partnerships by reducing costs and time efforts. (-> FT48)
- The aspect of virtuality should not be seen as a constraint but as an opportunity for SMEs to plug competence gaps and build new competencies for developing and producing innovative

products through integration, done within a sustainable and globally-competitive networked product development community. (-> FT98)

- Virtual teams could be more effective if we move ahead in the field of competence management using the platform as a pool of various possibilities. (-> FT118)
- Information related to the competences and requirements of stakeholders needs to be as detailed as possible in order to provide a methodology that allows the match of requirements with coherent competences. (-> FT216)
- A feedback procedure should be established to get knowledge about the quality and the success of the projects. This is the only possibility to provide a trustworthy environment. (-> FC2)
- Team-building should be based on defined criteria for required competencies. Electronic tools and web-based communication systems should be adapted on those soft aspects to provide a simplified and extended worldwide access to a wide range of product development resources. (-> FC26)

TEMI$					
FT216:	The system should provide an unerring combination of competences to assure a network of sustainable partnerships in the process of new product development.				
FT216	**combination of competences**	**network**	**sustainable partnerships**	**new product development**	**conclusion**
Time	reduce time by the right matching processes	always accessible	long-term	being up-to-date	**Information related to competences and requirements of stakeholders needs to be as detailed as possible to provide a methodology allowing to match requirements with coherent competences**
Energy	algorithm	multi-disciplinary competences, knowledge +skills	human capital	cognitive efforts	
Material	new technologies	experts, knowledge, competences		best material for new products	
Information	sets of requirements and specifications	multi-disciplinary view on a topic	easy to access	guidelines – plans for design of innovative products	
Costs	for construction of an effective matching system			personnel cost, material costs, quite high	

Figure 6. Example of the method TEMI$

In the final step of our functional analysis, the importance of the key functions could be measured so as to provide profound recommendations. Therefore, different categories should be established which imply several functions which are regrouped here in the hierarchical tree. The weighting in terms of percentages varies according to the point of view of the stakeholder and also the different categories diversify depending on the purpose of the weighting. Figure 7 gives only an brief extract of this method.

Even if the hierachical tree could vary in several ways, this method establishes a common basis to get a clear picture of the importance and the hierarchical order of the functions.

6. Conclusion

The functional analysis allowed us to gain insights into the complex system of competence management in order to create competitive virtual teams for supporting innovation processes in SMEs. It offered us a holistic picture about key elements and helped us to identify interrelations between the different concepts of virtual team building, compentence management or innovation processes in SMEs. To be able to describe the research field from a systemic point it was helpful to master the complexity of it and to investigate new perspectives in order to obtain new research directions. We are now able to formulate coherent research questions for future studies in this field and to take new ideas and important central features into account. The formulation of functions, their analysis and the hierarchical tree weighting offer an optimum of usability of the products and services to be developed.

The development of a system of methodology for competence management to create competitive virtual teams for supporting innovation processes in SMEs is a complex task. This and other factors need to be taken into consideration in order to obtain exploitable results.

Our interest lays in providing a framework for the constitution of virtual teams that is adaptive to each context. Providing a methodology requires different approaches. We suggest in the next step to implement our theoretical approach in the industrial practice. The future works will be about the application of this method in enterprises, in order to validate the generic aspect of the functional analysis. As we have shown, the functional analysis gives recommendations for the constitution of virtual teams in different contexts. Our crucial interest is now to be able to know which functions will stay the same even if the context changes.

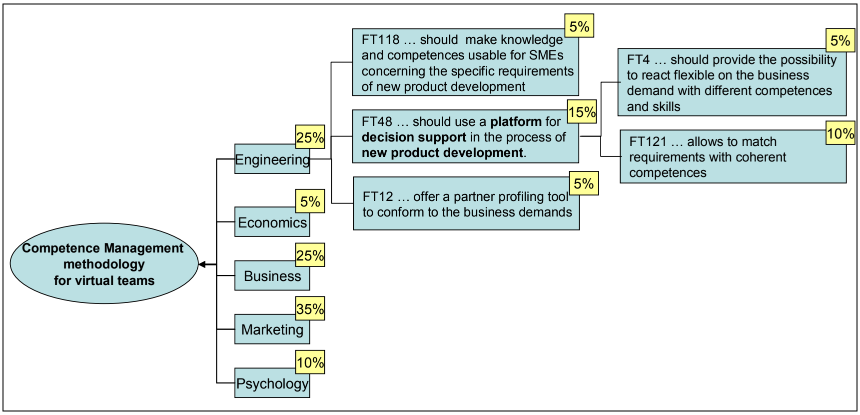

Figure 7. Example of the hierarchical tree of functions

References

Apte, La Méthode APTE (®) d'AV/AF, (2000) Petrelle

Galbraith, J.R. (1996): Designing the innovating organization. In: Starkey K. (1996): How organizations learn, London: International Thomson Business Press

Grenier, R. and Metes, G. (1995): Going virtual: Moving our organsiation in the 21st Century Upper Saddle River, NJ: Prentice Hall

Griffith, T. L., Sawyer, J. E., and Neale, M.A. (2003): Virtualness and Knowledge in Teams: Managing the Love Triangle in Organizations, Individuals, and Information technology, MIS Quarterly, no.27, pp. 265-287

Horvarth, L., Tobin, T.J. (2001): Twenty-first century teamwork: Defining competencies for virtual teams, in: Virtual teams, Volume 8, pp. 239-258

Huanga, W., Weib, K., Watsonc, R.T, Tanb, B. (2002): Supporting virtual team-building with a GSS: an empirical investigation

Kleef van, J.A.G., Roome, N.J. (2007): Developing capabilities and competence for sustainable business management as innovation: a research agenda, Journal of Cleaner Production, no.15

Observatory of European SMEs (2002): European Commission, DG Enterprise, p. 9

Prahalad, C.K., Hamel, G. (1990): The core competence of the organization, Harvard Business Review Maye

Snodgrass, T.J. (1986): Function Analysis – The Stepping Stones to Good Value, CVS at KASI; Muthiah, CVS

Whipp, R., Clark, P. (1986): Innovation and the auto industry: Product, process and work organization, London: Francis Pinter

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