RE-USE OF ENGINEERING DESIGN RATIONALE IN FINNISH SME PROJECT BASED INDUSTRY

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Abstract

This study presents views on barriers of re-use of engineering design rationale. The research data was gathered by interviewing 29 persons who work in 19 different Finnish SME engineering project based companies. The topic was studied on three main levels: due to actions of business management, due to actions of project team and due to individuals own action. From this perspective, six categories of barriers of tacit knowledge re-use were found: Time management, Tools and documentation practices, Working methods, Validity of information, Well-being at work and Distinction in competence.

Keywords: design knowledge, design practice, design management

1. Introduction

Knowledge has been identified as a primary driver of competitiveness. Especially in multinational corporations there has been a growing interest in the management of intangible resources and the structure, processes, mechanisms and organization of to facilitate a more effective internal and external flow of knowledge (Argote and Ingram, 2000; Gupta and Govindarajan, 2000; Riege, 2005). These studies in the management domain present an extensive overview of possible knowledge transfer facilitators and barriers in large-scale multinational companies. In engineering companies the ability of experts to provide rationale of past design solutions is one of the most significant information need (Heisig et al., 2010).

The management, capturing and sharing engineering design knowledge cannot rely solely on social interaction even though it is one existing procedure. Consultants and managers have explored and developed a variety of measures to improve knowledge management, to understand the structure of knowledge processes, and to identify preconditions for the integration of knowledge (Sveiby, 2001; Lampel et al., 2008; Berggren et al., 2011; Zhang and Cheng, 2015) However, the understanding of barriers for information sharing and re-use is still limited (Riege, 2007; Darlington et al., 2011; O'Brien, 2015).

Engineering design knowledge transfer is also an issue at small and medium size companies (SME). Success in design activities has a significant influence on profitability of a company. Lack of re-use on engineering design rationale in SME's result in cost of quality, continuous rush and difficulty to success in global competitive situation. It is known that ICT can enhance knowledge sharing by lowering temporal and spatial barriers between knowledge workers, and improving access to information about knowledge, nevertheless, there are other kinds of barriers for knowledge sharing - and they are based on motivation for sharing (Hendriks, 1999). The study by Ardichvili and others (2003) analyses deeply the issue of 'not-sharing'. The study indicates that, when employees view knowledge as a public good belonging to the whole organization, knowledge flows easily. However, individuals tend to shy away from contributing knowledge for a variety of reasons. Specifically, employees hesitate to contribute out

of fear of criticism, or of misleading the community members (not being sure that their contributions are important, or completely accurate, or relevant to a specific discussion). To remove the identified barriers, there is a need for developing various types of trust, ranging from the knowledge-based to the institution-based trust (Ardichvili et al., 2003).

In the search of relevant approaches and models on the barriers and enablers of capturing and sharing engineering design rationale the Serna´s maturity model of transdisciplinary, knowledge management is presented in the context of transdisciplinary research. The maturity model describes levels and different characteristics for transdisciplinary knowledge management. The operationalization consists of five levels of maturity and four main characteristics. "Transdisciplinary is a force which encourages to people representing different disciplines to transcend their conceptual, theoretical, and methodological individual orientations with the objective of developing a common research approach, based on common conceptual framework." (Rosenfield, 1992). The Serna´s approach is that transdisciplinary scientific knowledge is "achieved through the sharing of the bodies of knowledge of individual disciplines and the experience of each participating individual." (Serna, 2015)

The focus of this research is project based engineering organisations. Hobday (2000) argues that the project based organisations operates mainly at two distinct levels of activity: the project level (project management, project control, learning in projects) and the organizational level (strategy, top management, cross-project coordination, learning across projects). Knowledge processes in project based organisations (PBOs) are also affected by employees representing different areas of knowledge and being located in different "thought worlds" owing to their diverse professional and disciplinary backgrounds (Dougherty, 1992). Grabher (2004) shows that many project settings are characterized by dynamic interdependencies among projects. These interdependencies are shaped by such factors as time, space, and the number of organizations involved as well as reputation, professional ethos, and trust. Zahedi et al. (2016) have studied knowledge sharing challenges and practices in global software development and found six knowledge sharing challenges. These challenges are compared with the findings of this research.

There are only few studies about engineering design knowledge capturing and sharing in project based SMEs. One reason for the lack of studies is that it is difficult to get reliable information, since SMEs are seldom open enough for external researchers to analyse their activities. We managed to solve this problem as one of our research team member also work as a senior designer in a Finish SME engineering company. The goal of this study is to bring new insight on re-use of engineering design rationale. Research question in this study is: What are the most essential elements in project teams that prevent or enable re-use of expert design rationale of technical systems?

2. Research strategy and research method

This is an empirical, data based qualitative study about project team engineers' views about capturing and sharing knowledge, following the steps presented by Miles (1994). First, the data is gathered and it is analyzed. Then relevant literature is studied and compared with the results of the analysis. In the next study the hypothesis is formulated and it is verified with the same people that was interviewed in the first step. The research data was gathered by interviewing 29 persons. They work in project teams or in engineering management activities within 19 different Finnish SME engineering companies. The demographical information on informants is given in Table 1. Their educational background is following: 21 % of informants are graduated with M.Sc. degree qualification, 72 % with B.Sc. degree qualification and 7 % have vocational degree qualification. As it can be seen in Table 1 the age group 51-65 years is emphasized because they are close to interview's own age 64. The obvious imbalance between female and male informants is because there is not many female engineers in this age group.

Informants were selected based on their professional skill and experience in Finnish SME's. They have worked in number of companies during their work careers. The Interviewer has worked in same companies with informants and therefore he was able to select a representative sample based on their expertise.

The Interviewer is graduated from a university and he has 35 years engineering background in different Finnish SME engineering workshop companies. The interview process included two stages. At the first

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stage, semi-structured question form was send to the informants. They were asked to answer questions which topics were related to: Sharing of engineering knowledge, human capital, work ethics and ethical values, social capital and organizational capital

Table 1. Demographical information on informants

Age	20 - 30	31 - 40	41 - 50	51 - 65	66 -	Total
Male	2	2	1	16	6	27
Female	1	1	0	0	0	2
Total	3	3	1	16	6	29

At the second stage, each informant was interviewed individually. The starting point for this discussion was their answers to the semi-structured question form and theme of the interview theme. In this situation, the informants explained their experiences from their work career.

The interviews were recorded and transcribed for the analysis. Based on the material it was analyzed what kinds of barriers for knowledge transfer the informant discussed about. Besides of the identified barriers it was analyzed who is the actor, who is responsible of the area related to the barrier. That means who has caused the situation in which the barriers appears or who is able to change the situation.

3. Results

The barriers of information re-use are categorized to three levels: due to actions of business management, due to actions of project team and due to individuals own action. This approach is in line with categorization in Hobday (2000). Perspective in this study is focused on project team level so this explains how project team engineers view the responsible actors. The viewpoint of business management is not included in this study.

3.1. Barriers caused by actions of business management

According to informants, business management has the most power to make and to solve the barriers of sharing tacit knowledge.

3.1.1. Time allocation and reserving time for capturing and sharing engineering design rationale

The informants made their conclusions based on fact that the matter was discussed with business management however resulting any change. Business management was considered to have good will to correct the problem but they could not offer any solution. Some informant's comments are listed below:

- Business management does not find it important to reserve time for sharing experimental knowledge.
- It is not reserved enough time for development of work community's common expertise.
- Tight project schedule does not make possible to share experimental knowledge.
- Horizontal knowledge transfer wane due to rush and vertical knowledge transfer does not work well.
- Time for sharing the knowledge is taken from my own work time and thus it is increasing projects costs.
- Lack of time is preventing recycling drawings among colleagues.

The issue of time management was recognized in 38 % of the interviews. These observations are well in-line with recent findings by O'Brien (O'Brien, 2015): The implementation of several knowledge management initiatives is hindered because staff do not have sufficient time. Knowledge re-use is not given attention when targets have to be met. Lack of time is present also in other studies

3.1.2. Tools and documentation practices

The interviews are not aware on any tools or data base where knowledge design rationale could be saved. Furthermore, it is not defined in the company, what is the important information for business that needs

to be saved. In addition, who is responsible of updating such a data base. However, interviews believe that information technology can offer suitable tools for this purpose. Some informant's comments are listed below:

- It is not known or understood to make documents.
- It is not easy to find knowledge of design rationale from company's fragmented data bases.
- There are no search engine for company's databases.
- Imperfect Intranet does not enable sharing of knowledge of design rationale.
- There are no digital discussion forum that would save problem solutions to a database.
- It is not known what other colleagues know.

The issue of tools and documentation practices was recognized in 79 % of the interviews.

These observations are well in-line with findings by O'Brien (O'Brien, 2015): Due to time issues and informal network dependence, there is a lack of formal systems use. There is a lack of ownership of knowledge. There are knowledge retention problems. The organization does not know its employees' skills. Findings by Riege are also in-line with the observations (Riege, 2007): While several researchers have investigated organizational processes, methods and mechanism as well as individuals' ability and motivation to enhance internal and external knowledge transfers and thus gain competitive advantages, there is very little empirical evidence about organization's initiatives and managers' actions on how to overcome diverse knowledge transfer barriers.

3.2. Barriers caused by actions of project team

In the project team level, the most important barriers of knowledge transfer in project team are working methods and validity of information.

3.2.1. Working methods

Many shortages were experienced in the actions of project team. This was justified due to lack of time. There are not enough meetings and minutes are not read and discussed. Some informant's comments are listed below:

- Ready plans and blueprints are not evaluated together.
- Open discussion culture is minimal.
- Colleagues do not gather for brainstorming.
- Information will not transfer and flaws in design will remain.
- Designer works alone and finally become excluded.
- Feedback from manufacturing is not received.
- Final meetings are not organized.
- Installation minutes are not opened.
- Existing software can't be exploited.
- Geographical dimensions and digitalization is not exploited.
- External network is not known.
- IT-orientation is weak. Not capable to exploit saved data and search experimental knowledge.
- Strong person in project team reduce willingness to express own opinions.
- It is not habit to ask an advice.
- Ideas and experiences discovered by other team members will not be used.
- Shared information is not understood duo to it's inadequately formulation.

The issue of working methods was recognized in 13/29 (45 %) of the interviews.

Similar results have been found in earlier studies in textbook of Bordegoni and Rizzi: People need to work together to reach the desired outcome rather than that outcome being achieved through 'selfish' participation constrained by contextual factors Challenges of globally distributed organizations are immense. The advent of Web 2.0 technologies has brought a new culture of sharing information on the Web where users can actively create, store, edit, access, share and distribute the content to larger audiences. (Bordegoni and Rizzi, 2011)

3.2.2. Validity of information

Almost all the interviews considered that designs are not updated at end of the project. This was seen as a serious issue. Especially unexperienced designers may be confused on relevance of design information. Some informant's comments are listed below:

- Design information is not argued.
- Mistrust on validity of own data.
- There is unconfirmed information that dare no to use.
- Blueprints are not updated.

The issue of validity of information was recognized in 17/29 (58 %) of the interviews.

The issue of trust has been found in earlier studies by in textbook of Bordegoni and Rizzi: Trust fundamentally boils down to a trust-in capacities and abilities, and people need to make continuous assessments about whether or not they can rely on recommendations or advices that their colleagues offer. (Bordegoni and Rizzi, 2011)

3.3. Barriers caused by individuals own action

In the individual level, the most important barriers of knowledge transfer in project team are ambience in working environment and distinction in competence.

3.3.1. Well-being at work

Bad ambience in working environment easily leads to problematic behaviour between team members. Changes in company's organization, merging of company's easily causes tension. Some informant's comments are listed below:

- Bad interpersonal relations.
- Bad ambience in work environment, senior designer give up.
- Low work moral reduces co-operation.
- It is easier if you don't get involved.
- Retirement age is close, motivation disappears, and information is not shared.

The issue in well-being at work was recognized in 9/29 (32 %) of the interviews.

3.3.2. Distinction in competence

Individuals are proud of their competence. High competence may lead to power play and to dominating position in project team. Enabling junior member's professional development in the project team is seen important but senior members are not motivated to this. Some informant's comments are listed below:

- Expert is behaving unpredictable, it is better not ask.
- Values are not met, resulting silence.
- Underestimation of person results in silence.
- Senior is dominating, junior is not brainstorming.
- Relation between experts and novices is inadequate.
- Master-teaching-trainee -system is not used.

The issue in distinction in competence was recognized in 20/29 (68 %) of the interviews.

In previous studies, preventing factors on re-use of knowledge is considered to be related more on various processes between humans rather than in technological issues (Ajmal et al., 2009). Busby recognize cognitive and motivation factors as limiting reasons in knowledge re-use (Busby, 1999).

4. Discussion and limitations of the study

Sharing of tacit knowledge is a multi-level (management, project team, individual) issue that needs to be studied from a number of perspectives (Serna, 2015; Zahedi et al., 2016). Codification and personalization brings in versatile perspective to study the problem (Davenport and Prusak, 1998; Hansen et al., 1999; Wong and Tiainen, 2004). In addition management of people in an essential factor

in this issue. The categories that are identified in this study are related to each others. Due to weak time management in a company a documentation is not completed. On the other hand, time in a project will be wasted due to poor documentation of the previous project.

The most surprising results of this study are that the category of time management is seldom mentioned and that the category of distinction in competence is often mentioned among the informants. It was expected that lack of time would be explained as the reason for not sharing knowledge. However, the informants did not discuss that so often. Furthermore, the frequent mention of the category of distinction in competence was also a surprise. The category of distinction in competence is partly related the high number of older engineers among the interviewees, who considers relation between experts and novices unsatisfactory. Furthermore, some the informants' comments draw quite negative image of older engineers. The category of tools and documentation practices was mentioned most often.

This study is based in interviews with 29 persons. For a qualitative study this is a typical numbers of informants (Sandberg, 2000). Instead, this number is not enough to give statistically relevant data. Therefore previously presented portions of preventing factors for re-use of tacit knowledge needs to be understood as an approximate number of it. However, the aim of our study was to identify the problems in the sharing knowledge of design rationale. For that kind of purpose, the interview material is sufficient.

Our practical observation is that work culture in large international companies is different from SMEs. More detailed analysis of this matter is topic of future studies. Value of the interview material is emphasized due to its explicit focus on a specific field, SME project based industry. There are not much studies published from this company segment, which employ a great number of people. Although this sample was taken from one country only, it is to be expected that SMEs in other countries are facing similar issues.

In further studies, we focus more deeply on phenomena that exists behind barriers of information transfer. Understanding these phenomena make it possible to find solutions which reduces negative impacts and intensify positive impacts in re-use of engineering design rationale.

5. Conclusions

Understanding phenomena that exists behind barriers of information transfer makes it possible to find solutions, which reduces negative impacts and intensify positive impacts in re-use of engineering design rationale. In this study, we focused on Finnish SME project based industry.

Unexpectedly, time management was not considers as main reason. Instead, distinction in competence was frequently mentioned among the informants. The category of tools and documentation practices was mentioned most often. However, finding new technical solutions is not enough, but also some changes in organizational culture is needed.

References

Ajmal, M., Helo, P. and Kekäle, T. (2010), "Critical factors for knowledge management in project business", *Journal of Knowledge Management*, Vol. 14 No. 1, pp. 156–168. https://doi.org/10.1108/13673271011015633

Argote, L. and Ingram, P. (2000), ''Knowledge transfer: a basis for competitive advantage in firms'', *Organizational Behavior and Human Decision Processes*, Vol. 82 No. 1, pp. 150-169. https://doi.org/10.1006/obhd.2000.2893

Ardichvili, A., Page, V. and Wentling, T. (2003), "Motivation and barriers to participation in virtual knowledge-sharing communities of practice", *Journal of Knowledge Management*, Vol. 7 No. 1, pp. 64–77. https://doi.org/10.1108/13673270310463626

Berggren, C., Bergek, A., Bengtsson, L. and Söderlund, J. (2011), "Exploring knowledge integration and innovation", In: Berggren, C., Bengtsson, L., Bergek, A., Hobday, M. and Söderlund, J. (Eds*.), Knowledge Integration and Innovation: Critical Challenges Facing Technology-based Firms,* Oxford University Press, Oxford, pp. 61-77. https://doi.org/10.1093/acprof:oso/9780199693924.003.0001

Bordegoni, M. and Rizzi, C. (2011), *Innovation in Product Design - From CAD to Virtual Prototyping*, Springer, pp. 188.

Busby, J.S. (1999), "The Problem with Design Reuse: An Investigation into Outcomes and Antecedents", *Journal of Engineering Design*, Vol. 10 No. 3, pp. 277-296. https://doi.org/10.1080/095448299261335

Darlington, M., Howard, T., Ball, A., Culley, S. and McMahon, C. (2011), "Data Management planning in Engineering Design and Manufacturing Research", *Proceedings of International Conference on Engineering Design (ICED 11), Copenhagen, Denmark, August 15-18, 2011,* p. 11.

Davenport, T. and Prusak, L. (1998), *Working Knowledge: How Organizations Manage What They Know*, Harvard Business School Press, p. 224.

Dougherty, D. (1992), "Interpretative Barriers to Successful Product Innovation in Large Firms", *Organization Science*, Vol. 3 No. 2, pp. 179–202.

Grabher, G. (2004), "Temporary Architectures of Learning: Knowledge Governance in Project Ecologies", *Organization Studies*, Vol. 25 No. 9, pp. 1491–1514. https://doi.org/10.1177/0170840604047996

Gupta, A.K. and Govindarajan, V. (2000), "Knowledge flows within multinational corporations", *Strategic Management Journal*, Vol. 21 No. 4, pp. 473-496. https://doi.org/10.1002/(SICI)1097-0266(200004)21:4<473::AID-SMJ84>3.0.CO;2-I

Hansen, M.T., Nohria, N. and Tierney, T. (1999), "What's Your Strategy for Managing Knowledge?", *Harvard Business Review*, Vol. 77 No. 2, pp. 106-116.

Heisig, P., Caldwell, N.H.M., Grebici, K. and Clarkson, P.J. (2010), "Exploring knowledge and information needs in engineering from the past and for the future - Results from a survey", *Design Studies*, Vol. 31 No. 5, pp. 499–532. https://doi.org/10.1016/j.destud.2010.05.001

Hendriks, P. (1999), "Why Share Knowledge? The Influence of ICT on the Motivation for Knowledge Sharing", *Knowledge and Process Management,* Vol. 6 No. 2, pp. 91–100. https://doi.org/10.1002/(SICI)1099-1441 (199906)6:2<91::AID-KPM54>3.0.CO;2-M

Hobday, M. (2000), "The project-based organisation: an ideal form for managing complex products and systems?", *Research Policy*, Vol. 29 No. 7–8, pp. 871–893. https://doi.org/10.1016/S0048-7333(00)00110-4

Lampel, J., Scarbrough, H. and Macmillan, S. (2008), "Managing through projects in knowledge-based environments: special issue introduction by the guest editors", *Long Range Planning*, Vol. 41 No. 1, pp. 7-16. https://doi.org/10.1016/j.lrp.2007.11.007

Miles, M.A. and Huberman, A.M. (1994), *Qualitative Data Analysis: An Expanded Sourcebook,* Sage Publications, pp. 50–72.

O'Brien, J. (2015), "10 Practical findings from the deployment of an exploratory knowledge management framework.", *VINE*, Vol. 45 No. 3, pp. 397-419. https://doi.org/10.1108/VINE-08-2014-0051

Riege, A. (2005), "Three-dozen knowledge-sharing barriers managers must consider", *Journal of Knowledge Management*, Vol. 9 No. 3, pp. 18-35. https://doi.org/10.1108/13673270510602746

Riege, A. (2007), "Actions to overcome knowledge transfer barriers in MNCs", *Journal of Knowledge Management*, Vol. 11 No. 1, pp. 48-67. https://doi.org/10.1108/13673270710728231

Rosenfield, P.L. (1992), "The potential of transdisciplinary research for sustaining and extending linkages between the health and social sciences", *Social Science & Medicine*, Vol. 35 No. 11, pp. 1343–1357. https://doi.org/10.1016/0277-9536(92)90038-R

Sandberg, J. (2000), "Understanding Human Competence at Work: An Interpretative Approach", *Academy of Management Journal*, Vol. 43 No.1, pp. 9-25. https://doi.org/10.2307/1556383

Serna, E.M. (2015), "Maturity model of transdisciplinary knowledge management", *International Journal of Information Management*, Vol. 35 No. 6, pp. 647–654. https://doi.org/10.1016/j.ijinfomgt.2015.07.002

Sveiby, K-E. (2001), "A knowledge-based theory of the firm to guide in strategy formulation", *Journal of Intellectual Capital*, Vol. 2 No. 4, pp. 344-358. https://doi.org/10.1108/14691930110409651

Wong, R. and Tiainen, T. (2004), "Are You Ready for the Right Knowledge Management Strategy: Identifying the Potential Restrains Using the Action Space Approach", *eBRF Conference Proceedings, Tampere, Finland, September 20-23, 2004,* pp. 480-490.

Zahedi, M., Shahin, M. and Ali Babar, M. (2016), "A systematic review of knowledge sharing challenges and practices in global software development", *International Journal of Information Management*, Vol. 36 No. 6, pp. 995–1019. https://doi.org/10.1016/j.ijinfomgt.2016.06.007

Zhang, L. and Cheng, J. (2015), "Effect of knowledge leadership on knowledge sharing in engineering project design teams: the role of social capital", *Project Management Journal,* Vol. 46 No. 5, pp. 111-124. https://doi.org/10.1002/pmj.21525

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