The Future of Engineering Work
Increasing Flexibility in Work Content, Environment and Processes

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Keywords: Engineering Work, Virtual Work, Future Workplace, Collaborative Learning.

Abstract: This article presents an exploratory study of the trends affecting engineering work in the future, and their implications for managing engineering processes within companies. In many industries, the future workplace will be significantly different from that of today, changing the content of the work, the working environment and the way we work. In this study the effects of these workplace changes are discussed, based on both literature and practical experiences, from an engineering point of view as an example of highly knowledge-intensive work, and further research needs are identified.

1 INTRODUCTION

There are numerous drivers of change for workplaces in different industries. Especially in knowledge-intensive service businesses such as engineering, the managers are striving for novel ways of organizing work more effectively in distributed, increasingly virtual organizations where the technological tools are constantly evolving and the tasks and the knowledge needed for achieving them become scattered and fragmented. The academic community has noted the changes of the society and working environment quite broadly in different fields of study, and the extant literature on the future trends of working is substantial for example in psychology, sociology and management (see Khallash and Kruse, 2012 for a recent overview). However, the practical implications of these changes are still under debate, and studies concentrating especially on knowledge intensive working environments are still scarce.

The research question we aim to answer is what implications for practice and further research needs can be identified based on the trends affecting engineering work in the future? As a method of study, we use both literature research and interviews of managers and engineering professionals as data for identifying first the relevant workplace future trends and second their implications for engineering work.

The future trends of working and workplace have been discussed by several authors in recent years, both by academics and private consultants. In addition, we have referenced articles and academic dissertations on the future of engineering education (Korhonen-Yrjänheikki, 2011; Sunthonkanokpong, 2011; Shuman et al., 2002; Rugarcia et al., 2000), which closely relates to the way the engineering work is considered to change (Zhou, 1998).

The aim of this paper is to identify working life trends that are important especially for knowledge-intensive engineering profession, and to present a discussion on the implications of these trends. The implications are analysed and classified into categories of work content, work environment and work processes. As a result, our study shows the need for change in practical management and organization of work in engineering organizations in all of these three categories. The study also identifies needs for future research, such as the social aspects of collaboration and learning, in addition to technical solutions, which are currently receiving considerable attention in research.

This paper is organized as follows: after the introduction, the second section of the paper gives an overview of the identified future trends affecting work and specifically engineering work based on earlier literature. The third section briefly discusses the research methods used for the empirical part of the study, and the fourth section presents the results of the interviews and summarizes the findings of the

Lampela H. and Papinniemi J..
The Future of Engineering Work - Increasing Flexibility in Work Content, Environment and Processes.
DOI: 10.5220/0004512006010607
In *Proceedings of the 9th International Conference on Web Information Systems and Technologies* (FWP-2013), pages 601-607
ISBN: 978-989-8565-54-9

study. The paper ends with a summary of the implications of these findings in section five offering both practical recommendations for managers and suggestions for future research topics.

2 TRENDS AFFECTING ENGINEERING WORK

2.1 Changes in Working

The macro trends of the societal changes are reflected on working life as well. The discussion on the quality of working life has been rising in Japan, Europe and the US since the 1980's. In developed economies, we are now moving from industrial era to a knowledge-based economy (Korhonen-Yrjänheikki, 2011), and this has several effects on working.

Khallash and Kruse (2012) have studied the future of work in terms of work-life balance, and found that research on the future of work is often lacking facts and proper analysis, and the results are speculative and normative by nature, either too optimistic or too pessimistic. They suggest that the new technology and new decentralized organization forms will allow for better work-life balance. The attitudes towards work are changing, as well as the definitions of what is considered working, where it is executed and how (Khallash and Kruse, 2012).

As the view on work is changing, so is the motivation for working. According to studies, future knowledge workers will need to be more self-motivated than today, and their own expertise and possibilities of developing it further act as a source for work motivation in a challenging environment (Murtonen et al., 2008).

Knowledge-intensiveness is increasing in almost all types of work, and this leads to the fragmentation of tasks as the needed information is often scattered in different places. The importance of knowledge and information management as a task on personal, organizational and inter-organizational levels receives increasing attention. The importance of knowledge acquisition and sharing in networks is growing, and specialization of skills and knowledge of employees is driven further.

There is a broad consensus among organizational researchers that the organizational form of the future is increasingly virtual and project-based, and physical structures lose their meaning. In large organizations this means also global distribution of locations, but due to the advances in mobile or ubique information and communication technologies (ICT), work can be done anyplace and anytime (Khallash and Kruse, 2012). Despite the freedom and flexibility, this creates also challenges to work-life balance, as the expectations of being available also change.

Open and networked operating environment changes the processes and tools of collaboration. The social networks within own organization and also on personal level are rising in importance as hierarchical organization structures are evolving to better respond to this development. Decentralization of organizations is also reflected on technical solutions, particularly ICT. The rapid changes of available technology require flexibility in the ICT architectures of organizations, but also in the policies of how the tools are used. One recent example is the adoption of social media tools, which has had profound effects on collaboration practices.

2.2 Changes in Engineering Work

2.2.1 Engineering Discipline Definitions

Engineering work has its special role in the society, as according to the Engineers' Council for Professional Development (ECPD) the aim of engineers is to serve public safety, health, and wellbeing (Zhou,1998; Heikkerö, 2009). The special features of engineering science are defined as follows: it includes human-made objects of study that are defined in functional terms and evaluated with category-specific value statements, engineering design is part of technological sciences rather than natural sciences, idealizations are less far-reaching than in natural sciences, and exact mathematical solution is not needed if a sufficiently close approximation can be reached (Hansson, 2007).

Concerning engineering work, Zhou (1998) has found three types of definitions, focusing either on general features (all-inclusive definition), or on the inputs and outputs of the work, or on functional descriptions of the work. None of these definition types actually tells about how the engineering work is executed, and Zhou concludes that there is no consensus of the definition except that the design activities seem to form the core of engineering work (Zhou, 1998).

Engineering organizations are often among the first ones to adapt to the changes in the business environment, as due to the close connection of business and engineering, the changes in the environment are soon reflected in the engineering field:

"Because of the practical nature of the engineering discipline, the engineering profession reflects more than most professions the immediate environment within which it operates."
(Korhonen-Yrjänheikki, 2011; c.f. Allenby et al. 2009).

2.2.2 Changes in Society and Business Environment Affecting Engineering

The increasing knowledge-intensiveness and complexity, increasing virtuality of organizations, technological development and convergence, and increasing openness and networked structures are all reflected in working. The above-mentioned five trends are chosen based on Korhonen-Yrjänheikki (2011), for basis of our discussion because of their direct link to the future of engineering, and because they are agreed upon by several authors.

Rugarcia et al. (2000) have recognized challenging factors for future engineers, that are very similar to the trends presented by Korhonen-Yrjänheikki (2011): proliferating of information, multidisciplinarity of technological development, globalized markets, participatory corporate structures and rapid change. In addition to these, they discuss two factors, endangered environment and emerging social responsibility, which are not included in our study.

As discussed earlier in section 2.1, the increasing knowledge-intensiveness of the society is shown in the fragmentation of tasks and scattered information. This is true also in engineering, where for example design information management and product lifecycle information management have had several new concepts and tools developed recently to organize the vast amount of data and to guarantee global open access to corporate design and product information. By developing the processes of reusing the design information and knowledge, engineering companies seek to diminish the time spent on looking for existing information, which is currently time-consuming (Silventoinen et al., 2012).

New organizational forms, increasing virtuality of the working environment as well as the global value networks of engineering companies are changing engineering work by offering possibilities for independence and freedom to choose the place and the time for working. This can have profound effects on the organization of science and technology work globally, since western industrialized countries are facing less students interested in the field and the supply of engineers is growing in developing economies in Asia. (Lewin and Zhong, 2013).

The increasing openness of the organizations also changes engineering tasks by requiring more information sharing and collaboration with stakeholders than before, and the open innovation paradigm (Chesbrough, 2003) is changing the traditional view of design and development work. Understanding of value networks and interpersonal and cultural skills become critical in the new operating environment (Korhonen-Yrjänheikki, 2011).

The rapid development of technology and convergence of different fields of technology present opportunities for solving new types of problems and achieving complex system changes. This will require the engineers to find novel ways of combining interdisciplinary knowledge (Allenby et al., 2009; Rugarcia et al., 2000). The technological change will reflect also on the tools of the engineers; the working environment will be increasingly virtual and ICT-driven with tools for specialized purposes available. Especially the shared virtual working spaces and simulation tools will increase their importance in the engineering work.

As the complexity of the society is increasing, researchers are calling for a system focus and system-level understanding from engineers. In the future, engineering problems are undefined, appear within non-standardized social and technical processes, and require ability to define problems rather than solve them, collaborative learning, networking and creative learning. (Allenby et al., 2009; Sunthonkanokpong, 2011).

3 RESEARCH METHODOLOGY

3.1 Empirical Research Process

After the identification of trends, based on a literature overview presented in the previous section, we combined the results with empirical data from qualitative managerial interviews on the topic of collaborative and virtual team engineering work and learning, and its challenges and possibilities. The interviews have taken place in three Finnish multinational leading-edge high-technology corporations operating in business to business machinery and heavy industry equipment, ICT, and industrial equipment and services fields during 2008-2011. The companies were chosen based on previous or ongoing research project contacts and

on their known interest in virtual working and new working practices.

Data from altogether 9 individual interviews has been used in this study. This resulted in repetition of similar themes in the answers, which is a sign of qualitative data saturation (Easterby-Smith et al., 2008). The interviewees generally represented middle management or product development management of the company, had long experience on virtual working and team leadership, and were aged between 30-60 years with 15-35 years of work experience. The working titles ranged from sourcing manager, supply manager, sales manager to R&D manager, program manager, development manager and general operations manager.

The interviewees were either asked personally to participate, or received a voluntary invitation email from their manager asking for their interest to participate in the study. All the interviews were individual, face-to face meetings where the researcher used a semi-structured interview guide, allowing the interviewees to answer the chosen topics freely. The interviews took on average 60 to 90 minutes each, and the sessions were recorded and transcribed afterwards.

3.2 Data Analysis

The interview material was analyzed using a heuristic and inductive qualitative content analysis approach (Elo and Kyngäs, 2008), searching for interviewee answers regarding all the future-related change aspects of engineering work mentioned by the interviewees. The analysis was conducted by the same researcher as the original interviews. Based on the interviews, the classification of themes was made into three categories: the content, environment and processes of working. The data was organized in tables according to these themes and some illustrating quotations were found. The results of the analysis are presented in the next section.

4 FINDINGS

4.1 Interview Results

4.1.1 Content of Work

The interviewees had noted several changes related to the working life trends regarding the content of engineering work (what is done). The respondents experienced that the typical tasks during the working day of an engineer are changing, for example there is more information exchange and a need to stay constantly available. Also part of them said that a definition of what is considered working is under discussion in organizations, when they are laying the cornerstones on policies of distant working or virtual working.

The respondents utilize more open networks also outside their own organization as a source of information, and have more frequent customer contacts than before, as a result of closer integration of technical departments to sales support or business development. All this requires more communication skills than before, which was expressed by an interviewee:

"In global operations you cannot highlight this enough, communication skills and interaction competences in general."

They send short messages via SMS or chat to find out things fast, and considered information overflow and managing it a core challenge in their job. The majority of them regarded the development of their personal expertise (often specialized technical area) as a very important part of their tasks, and part of them had also noted the change from problem-solvers to problem definers, which was expressed for example as an unclear specification of what needs to be done.

4.1.2 Working Environment

According to the interviews, the changes in the working environment (where the work is done) are considerable. The increasing virtuality in working manifests as freedom of choosing the workplace and as new efficient tools and less hierarchy, but also as technical problems and unclear decision-making roles. Distance working, shared virtual working environments and virtual meetings that are spreading fast as the technology has matured also mean thorough changes in the thinking and attitudes within the organization as well as in the physical office environment. One respondent described his attitude towards new virtual tools as follows:

"I wish the tools were as easy and fast to learn as possible, so that we could just get on with them and could create the feeling of being present."

The effects of the increasing possibilities of virtual working in the organizations are manifold: on one hand, as the engineer does not necessarily have a shared physical working space with others and both the time and place of working can be flexible, this can be an advantage for work-life balance, but

on the other hand, loosing the feeling of belonging to an organization can become a challenge. As an example, one respondent said she had a feeling of "falling between teams", and another respondent continued on internal communication:

"When I need to get information, I always have to pull it. If you are around, the information is typically pushed. You get an email from somebody, someone comes to tell you something…. and [if] you are not around, so he will say ok, he will be informed later… but in the end of the day you are not informed at all."

4.1.3 Work Processes

The interview answers regarding the changes in engineering work practices and processes (how the work is executed) show firstly the versatile collaboration needs to persons and groups from different backgrounds, not only technical specialists. Secondly, adopting new (software) tools and learning to use them effectively also changes the work processes considerably. In a virtual setting, for example the meeting practices and expectations of the preparations or the outcomes are different than in a traditional face-to-face situation. As one interviewee said:

"The meeting mechanisms and communication have changed, now we guide the meetings through action points and make sure in the end of the meeting that everybody has understood what needs to be done and who does it".

Access to shared databases within own organization or even with partners means new precautions to protect information as well as to share it. Considering the networking and open access to information, some respondents said that sometimes their own personal networks as well as formal organizational networks are used when finding a solution to a specialized technical problem.

4.2 Summary of Findings

The findings of the study from the literature and from the interviews are combined and summarized in the Table 1 below. It shows the significant working life trends for engineering work identified in the study and the implications of these trends for practical engineering work classified into the categories of work content, environment and processes, although in practice some trends and implications are partly intertwined and overlapping.

Table 1: Future trends and their implications for engineering work.

Trends affecting engineering work	Implications for engineering work
Knowledge intensity	Content: fragmenting tasks, scattered information, special-ization and self-motivation Environment: access to information anywhere Processes: efficient tools for design and product information management, information reuse
New forms of organizations, increasing virtuality	Content: changing definition of work, changing attitudes Environment: virtual tools and location independence, mobility Processes: less hierarchies, new collaboration practices, social media
Open and networked environment	Content: versatile information sharing and collaboration in networks Environment: Using own personal networks in addition to official networks Processes:understanding value networks, interpersonal and cultural skills
Technological development and convergence	Content: new possibilities through combining technologies, opportunity for complex system changes Environment:decentralization of ICT, availability of virtual and simulation tools and dynamic changes of tools Processes: new ways of combining interdisciplinary knowledge needed
Complexity	Content:problems undefined, work is more problem definition than problem solving Environment: non-standardized social and technical processes Processes: need for system understanding and support for collaborative learning

5 CONCLUSIONS

5.1 Contribution of the Study

This study has added the current knowledge on the

future trends of working especially focusing on identifying the trends relevant to knowledge-intensive engineering work. The literature findings are strengthened by empirical data from managerial and specialist interviews, offering a practical confirmation to the issues found. Also, the study contributes to the discussion on the implications of these trends, classifying the implications into three main categories of the work content, work environment and work processes. The recommendations for practice and the future research topics are presented next.

5.2 Recommendations for Practice

The practical implications of the trends changing engineering work are vast for managers in organizations. They need to rethink the organization of work in all three aspects, what needs to be done, where it is done and how it can be done most effectively. Flexibility in all these aspects needs to be enabled if talented workforce is to be retained, and in a specialist organization such as engineering, designing and implementing these changes towards more flexible working cannot be left only as the management's responsibility.

The changes in business environment reflect directly to engineering work because of the practical nature of the field. Growing complexities of the business environment require new ways of collaborative problem-solving, which leads to the need for collaborative learning and global learning environments also in the workplace. Creating an environment (physical and virtual) that enables both flexibility and freedom for the individuals and creative collaborative working and knowledge sharing at the same time is a paradox that needs to be solved in engineering organizations. The social aspects of work are emphasized in the future, and organizations have to find new ways to support building trust and team identity, and commitment to common goals in a distributed, often virtual setting.

On an individual level, the managers in specialist organizations have to enable the continuous development of the specialists' knowledge, which is an important factor for work motivation. The motivation is based on own expertise and on the significance of the tasks, so these aspects need to be highlighted in the organization. The managers also have to accept a higher level of organization-independence of the employees, as the commitment to work is built increasingly on own expertise and the task and project at hand, not necessarily on the organization. This also signals a change in the so-called psychological agreement between the company and the employee.

5.3 Future Research Needs

Engineering work has been studied in this paper as an example of knowledge-intensive specialist profession. Thus, it can be useful for researching other similar fields as well. This study has provided the starting point for multidisciplinary research on the future of working in knowledge-intensive environments. Specifically, more needs to be known on the following topics:

- The social aspects of collaboration in engineering and collaborative learning
- New factors of work motivation and commitment, work-life balance
- Possibilities of new technologies such as social media tools to support collaborative thinking and learning, and generating creative solutions

As a conclusion of the research needs, several technologies that enable the trends and changing working practices already exist, but more research needs to be done on the social aspects, attitudes and thinking patterns of people. In the future, research will be focused in concurrent design of company's needs and worker's needs in virtual engineering workplace, to ensure both the quality of working life and sustainable competitiveness of companies.

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