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Raise It, Feed It, Keep It – Building a Sustainable Knowledge Pool Within Your R&D Organization

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1. Introduction

In light of the increasing globalization and economic competitiveness of the emerging countries, a key to competitive advantages of the western European countries, the United States and Japan lies in leveraging their innovative potential. With regard to the costs of living, social security systems and costs of labor, the industrialized countries can hardly compete with the emerging countries in the producing industry. Since neither Europe, the US nor Japan can beat the low production- and low technical development costs of the emerging countries, it is vital for their economies to focus on their key competences: The stimulation and driving of new innovative products to the market by means of inventions and patents within the R&D (research & development) industry.

Pursuing this target does not only imply high quality education in science and engineering. The actual economic value reveals itself in the researchers' and scientists' industrial careers, when their knowledge is applied to solving technical problems and is transformed into economic return in terms of inventions, patents and products. Hence, we need to realize the importance not only to recruit high quality experts for our research and development, but furthermore to preserve and build on this knowledge throughout the organization in order to gain a sustainable return of the high Western labor costs through innovative new technologies and scientific findings.

This target can be achieved by improving two main aspects within a company's R&D organization: Firstly by creating conditions that secure long term employment of the researchers, and secondly by understanding, improving and nurturing the inventors' communication within the organization.

2. State of research

The Western industry is based on its innovative power in research and development. There is a growing demand for highly skilled personnel in science and technology, such as researchers and engineers (BMBF, 2010). The aim must be to include the whole range of the innovative and inventive potential. Especially women represent a high educated potential labor force, whose potential has not been fully tapped into yet.

In R&D most work structures are team-based as this helps to solve creativity demanding problems and to stimulate innovation. A potential benefit of diversity regarding teamwork in R&D such as differences in education, national background, age or gender is still a research topic that is not fully explored.

The human resources development of female experts and executives in R&D gains rising importance as a critical success factor. In many cases the CEO of a high technology company is the former head of the R&D department (Hartmann 2007, 2009). Looking e. g. at the automotive industry, these individuals were often pioneers with excellent expertise. Within the high technology industry an important indicator for R&D success is expressed in the number of inventions and patents. In Germany and in all European member states women are not as often mentioned as inventors on a European patent as their share of the qualified workforce would indicate. A pronounced gap exists as e. g. in Germany about 6% of the inventors of European patents were female whereas about 12% of the qualified personnel (engineers and researchers) were female in 2003 (European Commission, 2006a, Busolt & Kugele, 2009). This gap is a result of a still dominant responsibility of women for family duties, a lower rate of overtime work and more part time work. Moreover women might tend to leave the R&D department earlier than men do as the possibility to combine family duties with a less challenging job in other departments as e. g. quality management or sales might seem more achievable. The latter departments rarely offer any possibilities to generate inventions. Disregarding the detailed reasons why women do not generate as many inventions as their share of the qualified personnel demands, we can state that qualified women represent the largest and most obvious potential to gain sustainable innovative power.

Some studies conclude that gender heterogeneous teams perform better than homogeneous teams as the team members have different ideas and perspectives (Frink, Robinson & Reithel 2003; Hirschfeld, Jordan, Field, Giles & Armenakis, 2005). Other studies indicate a source of friction and a therefore minor performance of gender heterogeneous teams (Jehn, 1995; Pelled, Eisenhardt & Xin, 1999; Randel, 2002). Most studies have forcibly compared homogeneous male teams with gender heterogeneous teams as women are still a minority in R&D (e.g. Burris, 2001). Being aware of this methodological drawback, Pearsall et al. conducted their study by assigning students to foursome teams (Pearsall, Ellis & Evans, 2008). The analysis of the functioning and the performance of homogeneous female teams in R&D is an important aspect on the way to tap the full potential of women in R&D. This is the only constellation in which women might experiment and perform in their own way of teamwork. The results reflect the view of women and lead to valuable improvement recommendations for companies in order to gain higher performing teams (Schone et al, 2011).

Furthermore the working conditions are different for a product development department, where narrower deadlines and high pressure for the achievement of objectives are dominant, and for a fundamental research department where more creativity, lateral thinking and rethinking of old beliefs are tolerated (Schone, 2009). Moreover the measurement of R&D team performance, i. e. creativity, innovation power, efficiency and net output by means of indicators is difficult. The performance of university scientists is measured by their scientific output, i. e. scientific publications (e. g. Martín-Sempere, Rey-Rocha & Garzón-García, 2002). The industry is more interested in the innovative

productivity and patents are needed to protect inventions. The number of patent applications is an indicator for the successful inventive achievement of individual researchers in science and technology. Patents, especially if they are not limited to only one country but include more countries as e. g. European patents do, are therefore an output indicator for R&D teams in industry (Busolt & Kugele, 2009). Nevertheless patents have the drawback that they do not differentiate regarding the effort and the creativity of the inventor team and it is therefore barely possible to assess the "real" value of a specific patent. Previous knowledge of the inventors as well as earnings from the products based on the patent is not observable.

3. Study methodology

In our study, we focused, among others, on the knowledge management of male and female inventors in the R&D industry. We observed that a number of highly qualified female researchers drift off their professional field of research during their professional career. How come those highly qualified female researchers seek positions outside their professional expertise and follow jobs in marketing, public relations etc. instead of research? What can be done to preserve the knowledge of these female researchers within the organization? A further research question was: what is the impact on innovation of homogeneous gender teams versus heterogeneous gender teams? The knowledge transfer and its influence on their respective innovative power were investigated as well as knowledge transfer patterns and communication structures. The questions that arise are how to improve the sustainability of knowledge within an organization on the one hand and to find out if inventor teams benefit from diversity within the team on the other hand.

Inventor teams work together for a limited period of time to generate a solution to a specific problem. Therefore they represent ideal conditions for the investigation of team work. In the German industry, there are only a limited number of homogeneous female inventor teams. However few, this allows a comparison between homogeneous female teams, homogeneous male teams and heterogeneous teams. We classify teams as successful when they comprise of inventors who have been granted a European patent, without further assessment of the actual patent value.

We concentrate on the specific determinants of gender impact on R&D inventions in the German industry. Hereby, our main research questions affect the four subgroups:

- homogeneous female inventor teams
- homogeneous male inventor teams
- heterogeneous gender balanced inventor teams
- heterogeneous male dominated inventor teams

In order to gather data and to contact the inventors, an SQL data base for all European patent applications within Germany was created for the years 2001-2006. Based upon raw data, which were specifically extracted by Eurostat for the EFFINET project, the following steps have been applied to the data base:

- Gender specific attribution (due to classification of the inventor's first name)
- Correlation of inventors to institutions or companies
- Correlation of inventors to specific industry branches

- Determination of inventor team constellation according to the above described team
- Characteristics (by gender specific attribution)

The data base includes the inventor's name, home address (as appearing on the patent application), company or institution and industry branch as well as the differentiation in which team constellation the patent was created.

Our study was conducted in three parts: a statistical analysis of the European patent database, a qualitative interview phase in order to gain insight into the innovation environments and to generate first hypotheses, and a quantitative online survey to verify and deepen our findings.

In the qualitative phase, 21 expert interviews with male and female inventors were conducted. The percentage of interviewees from each of the four target groups described above is distributed evenly. The interview participants have applied for at least one industry patent which was created within a team consisting of at least two inventors.

Our research interest during these interviews focuses on team work, innovative and organizational environment, communication structures and knowledge transfer impacting on the innovation- and patent creation processes.

Based on the hypotheses generated from these expert interviews a quantitative online survey served to verify our findings. A total of 357 inventors participated in this survey. Since the number of homogeneous female inventor teams is rather limited (approx. 300 European patents in Germany within the past 10 years) and a significant amount of those patents can be found in chemistry, pharmacy and medical equipment, our focus for the quantitative research lies on these industry sectors in order to guarantee an equal distribution of participants between the four team constellations (homogeneous female inventor teams, homogeneous male inventor teams, heterogeneous gender balanced inventor teams, heterogeneous male dominated inventor teams).

3.1 Statistical analysis of the European patent database

For over 40 years, the European Patent Organization has been in charge of granting and tracking the patents that have been applied for in Europe. In our study, we analyzed the European patents over the last 10 years according to their technological fields, economic sectors and the gender of the inventors. The aim was to figure out the appearance of female researchers in patenting as base for our research. The analysis of the patent database included the following major steps:

3.1.1 Institutional sector allocation

Patents are applied by industrial companies, universities, research institutions or individual inventors, but can also be applied in cooperation between these actors. Thus, data concerning R&D personnel are usually broken down by institutional sector. The patent database provides the name, country and address, but not the institutional sector of the applicants. To assign patent applicants/inventors to institutional sectors an institutional sector allocation was performed.

3.1.2 Inventor's first name gender assignment

Patent databases of the European Patent Organization do not provide the gender of the inventors. Therefore, an assignment of the inventor's first names to either male or female gender is a necessary precondition to obtain gender disaggregated statistics. First name gender assignment of a large number of names from different countries required a complex, multistep procedure to reach the best results. About 93% of all European names were identified as either male or female with variations between 81% and 100% for the European Member States.

3.1.3 Assignment of patents and inventors to technology fields

An International Patent Classification (IPC), a system of 31 technical units and eight sectors, was developed by the World Intellectual Property Organization. Patent data in the database were treated at the subclass level of the International Patent Classification; thus only the first four digits of the IPC were used for breakdown and aggregation.

3.1.4 Assignment of patents and inventors to economic sectors

Patent and inventor statistics, which usually are presented by technology fields (IPC), do not easily match with data on personnel in R&D, which for the business enterprise sector are usually broken down by economic sectors (NACE). In consequence, one cannot compare data of inventors with data of researchers easily (output-input comparison) without further data transformation from technology fields (IPC) into economic (industrial) sectors (NACE). Hence, methods have been applied to match IPC based technology fields to industrial sectors. As a result, technology fields are shared between industrial sectors.

3.2 Qualitative expert interviews

In the course of the expert interviews with the inventors the problem-centered interview (Wintzel, 1996) has been applied, a theory-generating method ranging between the narrative interview style and structurally guide lined interview. This semi-structured approach allows the experts (interviewees) to share knowledge based on their very own value system within the structural and content boundaries of the research focus.

The interview comprised a warm-up phase including the interviewee's general characteristics, such as professional career and current job position. Furthermore, the description of the specific innovation settings and knowledge transfer of the granted patent is split into an organizational-, team- and individual level with focus on the inventor's perceptions of team work, innovation- and efficiency determinants.

The whole interview has been recorded and subsequently transcribed. Additionally, a postscript of the interview has been generated, in which situation-dependent and non-verbal aspects, interpretation ideas and special characteristics of the interview have been noted.

A summarized and anonymized case description serves as a basis to consolidate the data and investigate central motives in order to generate theory. The interpretation of the data is intended to maintain its explorative, qualitative approach and is not intended to conclude

quantitative, generalizing statements. It was, however, the goal to develop first hypotheses to be further tested, verified and developed with the subsequent quantitative online survey among a larger group of participants.

3.3 Online survey

As stated above, the online survey served to test, verify and further develop the hypotheses generated from the qualitative expert interviews. The content of the 35-question survey includes a general section on the innovators' characteristics, such as professional education, career and family situation. This is followed by a generalized section on the participants' own opinion on organizational-, team- and individual influencing factors on the knowledge transfer, innovation culture and efficiency determinants within their R&D environment. Finally, the survey explores the innovation environment of one specific patent in its development and accompanying team processes. The survey questions have been answered in full by 310 inventors, representing team members of the four different inventor team constellations.

4. Do we sufficiently tap our inventors' knowledge?

Analyzing the European patent database, we found that there is a tremendous gap between the headcount of female researchers and scientists in R&D versus the headcount of female inventors. Exemplarily, the figure below shows the European patents of the year 2003 to illustrate the gap.

AT	Austria
BE	Belgium
BG	Bulgaria
CY	Cyprus
CZ	Czech Republic
DE	Germany
DK	Denmark
EE	Estonia
ES	Spain
EU	European Union
FI	Finland
FR	France
GR	Greece
HU	Hungary
IE	Ireland
IT	Italy
LT	Lithuania
LU	Luxembourg
LV	Latvia
MT	Malta
NL	Netherlands
PL	Poland
PT	Portugal
RO	Romania
SE	Sweden
SI	Slovenia
SK	Slovakia
UK	United Kingdom

Table 1. Country abbreviations

The statistical analysis served as a basis for our further research: What are the reasons that female researchers get fewer patents granted than male researchers? Are there conditions that prevent the exploration of their full innovative potential and their complete knowledge? If so, what are the determinants and what should an organization do to tap the full potential and hence expand their sustainable knowledge pool within the organization?

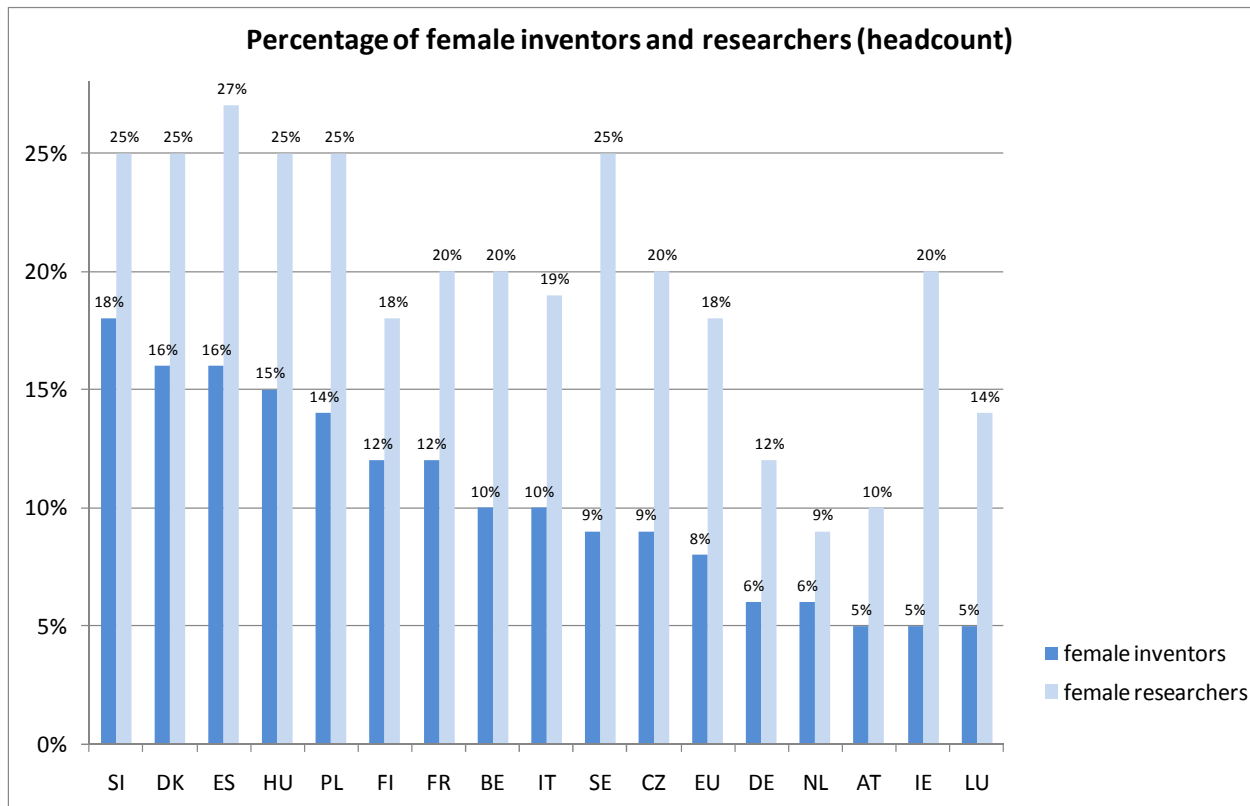


Fig. 1. Percentage of female inventors and female researchers in 2003, based on the European patent database and on EUROSTAT data (European Commission 2006a), 100% corresponds to all female and male researchers or identified inventors

5. The organizational need to nurture

The following section explains how to retain highly educated and experienced researchers within the organization in the long run. It discusses the obstacles and hurdles researchers are confronted with during their professional career, particularly with regard to work-family balance.

Especially female researchers are confronted with major life changes when they decide to start a family. Our study on the patenting- and inventing behavior of researchers shows that if organizational conditions within a R&D environment are managed badly, the inventors often cannot work according to their optimum level and are not able to use their innovative power sufficiently. The consequences of both, good and bad organizational management are revealed in this section. Furthermore, methods to optimize the researchers' conditions within the R&D department are suggested.

5.1 The communication of innovation

Our study revealed that in organizations with more than 1000 employees, there were not only a higher proportion of women in R&D departments, but also innovation systems that have more transparency, networking and support of the individual researcher. In smaller

organization of the sample, in contrast, structural measures to increase innovation are hardly existent. However, as stated by the respondents, researchers in smaller organizations have more freedom for research and creativity.

The evaluation of our expert interviews leads to two hypotheses in this specific context that are further explored in the quantitative online survey of the study. In order to establish a base for communication and knowledge transfer, the following findings of the expert interviews are further assessed.

A female researcher (heterogeneous gender balanced team) describes the situation in her company as follows: the employees in research feel well connected. There is a good working atmosphere. Networking and communication takes place as well on a formal (regular project meetings, information from the company) as on an informal level (meeting beyond working hours, spontaneous discussions, e-networking i.e. Xing). Due to the regular presentation of projects within the research department (2 hours every 2 weeks) the employees are well informed about other team projects. These meetings are also attended by part-time employees (from engineer level up).

A male scientist (homogenous male team) states that he summons a weekly meeting but apart from that a lot of spontaneous informal communication takes place in order to exchange knowledge. For this reason a personal network within the team and department is extremely important and stimulated by personal commitment.

Another female researcher (homogenous female team) describes a distinct, formalized communication system in order to encourage knowledge transfer within the company she is working for: Weekly division meetings, weekly group meetings, weekly discussion between employer and employee “jour fixe”, telephone conferences and meetings of the project teams (2-3 times per year).

While institutionalized communication structures (such as regularly scheduled team meetings) guarantee a comprehensible flow of information, communication paths among inventors are dominated by informal, spontaneous communication patterns, independent of the composition of the inventor team.

One male researcher (heterogeneous male dominated team) found it especially fruitful when theoretically oriented scientists discuss problems with practically oriented engineers and technicians. When sitting at a table together with different ways of thinking often ideas arise and thus these meetings might become quite productive. Regular team meetings also with experts from outside the project team should therefore be held regularly in order to generate knowledge.

In this context we learned from another interviewee (homogenous female team) that inventor teams are often composed of members from different project teams – “inventions happen”. According to the problem at hand an expert is called in from outside the team. The inventor team might be a subgroup of the bigger project team but its team members often originate from different departments. The average size of inventor teams is about 2-3 researchers, depending on the industrial sector. While the constellation of a project team is created for long-term teamwork (typically for at least the duration of one project, but also for several follow up projects) and is frequently determined by the organizational management, the composition of an inventor team underlies spontaneous characteristics, in

most cases issued by the inventors themselves: an “ad hoc team” is created to perform one specific task or to solve one specific problem. Once the task is completed and a patent application is filled in, the ad hoc team breaks up back into its assigned different project groups. Obviously the inventor team is not identical with the project team in most cases.

In summary it can be said, therefore, that for one thing networking, social processes and spontaneous discussions are crucial for effective knowledge transfer. For another thing formal communication structures as provided in regular meetings and presentations are equally important.

Results of the online survey regarding communication and knowledge transfer:

Having in mind what information has been given within the expert interviews regarding the importance of regular internal meetings with inventors and presentation of new inventions the answers to the online survey surprise: 72% of the researchers state that regular meetings of inventors within their organization and presentation of new inventions are not offered. Could this be an omission on the part of the organizations to stimulate the sharing of knowledge? On the other hand 77% of the researchers often (partially) make use of the freedom and tolerance for networking and informal communication during their working hours.

Corresponding to this only 47% of the respondents state that institutionalized meetings with participants during the invention process are (very) important to them. A different picture can be seen concerning the spontaneous possibility to discuss with participants (during the

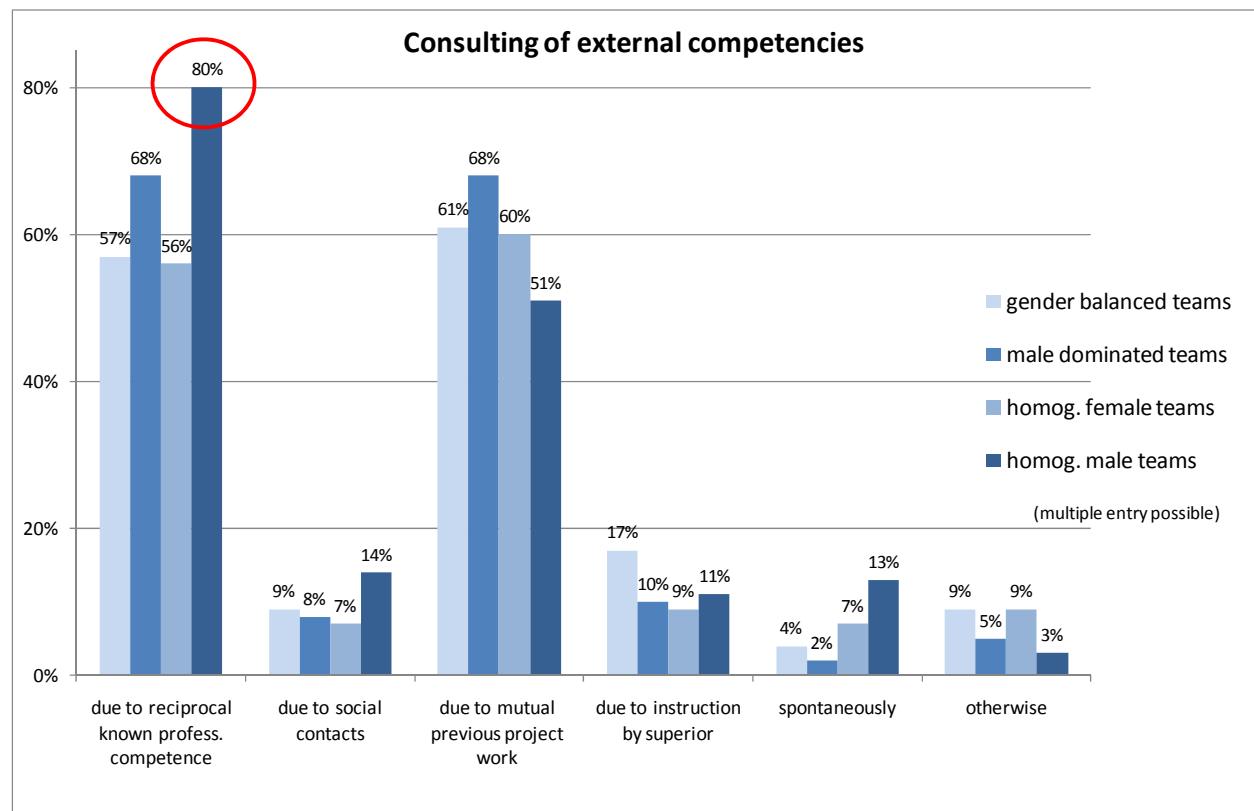


Fig. 2. Consulting of external competencies for innovation, 100% corresponds to all interviewees belonging to one of the four groups

invention process): this is (very) important for nearly 100% of the respondents. These results do not show any significant gender difference. Consequently the analyses of our expert interviews have been confirmed by this.

Likewise our result from the expert interviews concerning the consulting of external “knowledge” is confirmed by the participants of the online survey: Approximately 50% of the researchers state that experts from outside the project team have been consulted during the invention process mostly because of the known professional competence and former cooperation. In most cases, this knowledge was gained by informal communication and networking “in the aisles”: Researchers knew about competences of colleagues from other projects, asked them for support and later on developed the innovation and patent together. Therefore the inventor team is frequently composed differently from the actual project team (figure 2).

5.2 The participation of female inventors in communication and knowledge transfer

A female researcher (heterogeneous gender balanced team) concludes in the expert interviews that part-time work is difficult to organize: in general she handles the operative workload during the day. Time for invention needs calmness which she has at the end of the day. The company she works for offers part-time work as well as the co-financing of a daycare centre. As these options are quite recent she has only one child in order to arrange family and career.

Inventions and patents are frequently realized by overtime as the priorities during normal work hours focus on project work. Part time employees have less time flexibility (e.g. due to fixed child care hours) and thus have less time for creative brainstorming. For part time employees, it is therefore more difficult to actively participate in the innovation process.

Accordingly a male researcher (heterogeneous male-dominated team) quotes that working part-time in his team is hardly possible as much is discussed informally and spontaneously. During one year of parental leave, of course, much is missed. On the other hand technicians are used to quick changes of the market and thus have the ability to adjust. In his opinion the team only has a short-term knowledge advantage. The compensation of the returner’s knowledge deficit is a question of team spirit. He states that the perfect time for returning to work is the start of a new project which is new for all participants.

There was one best practice example, however, a female scientist (homogeneous female team) describing the perfect organization in which it seems possible to work as a part-time executive in R&D and have children at the same time. All members of the inventor team, including the head of the department herself, were part-time employees. Thanks to outstanding support systems within her company this female scientist states that overtime remains the exception. Even when patenting strongly it is possible for her to work part-time. In her opinion this is the result of the following factors: specific corporate culture, support through a patenting department, assistance within and between departments, arrangements for work-life balance, child care and social counseling within the organization. This observation leads to the assumption that the innovative capability of part-time employees is deeply affected by the organization’s management competences.

Another female inventor (homogeneous female team) has changed from R&D to part-time consulting for lobby work after having a child. Being head of a team requires commitment

and availability within the organization which in her opinion is not compatible with working part-time.

A similar view is held by a female respondent (heterogeneous gender balanced team) who claims that especially in innovative research industries it is most problematic to arrange children and career and not easy to find the perfect time to have children. As a consequence of this conflict she believes that professional paths diverge.

In summarizing it can be stated that male and female inventors show similar innovative potential in the beginning of their professional career. Both typically start their career and create their first patents in R&D departments as development engineers or scientists. They show the same characteristics regarding overtime and devotion to their work. Female researchers though commonly change their professional path when starting a family due to the demands of jobs in R&D and the difficulties of the compatibility of family and work. In conclusion it becomes obvious that parenthood influences the innovative performance of female inventors.

Results of the online survey regarding the participation of female inventors:

The options offered by organization for the compatibility of family and career resulting from the online survey are as follows: 75% of the respondents state that part-time is offered by their organization, 69% indicate flex-time, 45% home office whereas child day care facilities offered by organizations are only mentioned by 29% of the respondents. A wide difference can also be observed when asking by whom the children are being taken care of: 81% of the male researchers state that their spouses take care of the child whereas only 19% of the female researchers state this fact (figure 3).

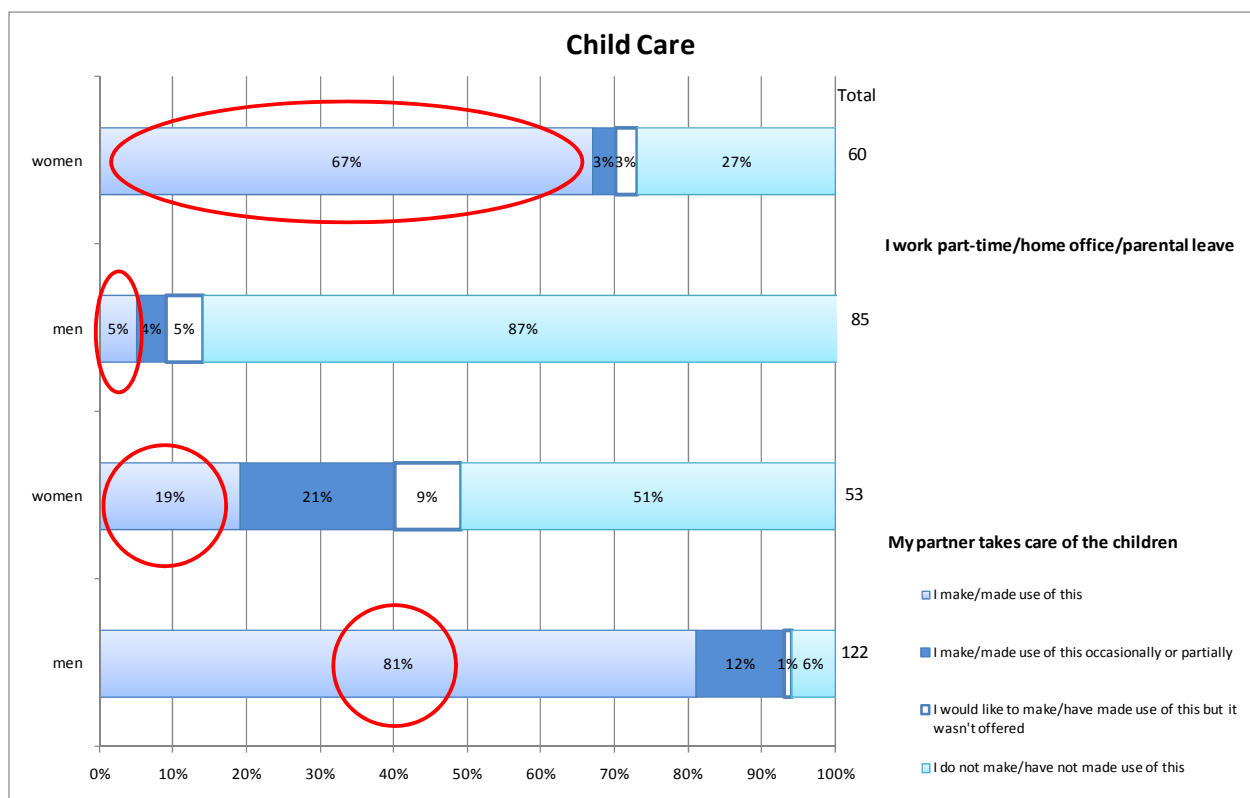


Fig. 3. Child care by female and male inventors, 100% corresponds to all male or female interviewees

Answers to our research question whether there were any gender-specific differences with regard to knowledge transfer during the innovation process show that women as well as men value informal communication and networking within their organization and project teams. Both regard the informal communication and networking as key to their professional success. As opposed to this, the importance of institutionalized meetings with participants during the invention process is very important to 19% of the homogeneous female teams while the other team constellations see this factor as less important (figure 4).

In our study, we found out that if there is a high proportion of part-time workforce the importance of formal communication through regular meetings rises. An increase of formal communication has positive impact on the integration of part-time employees as the randomness of information transfer is reduced.

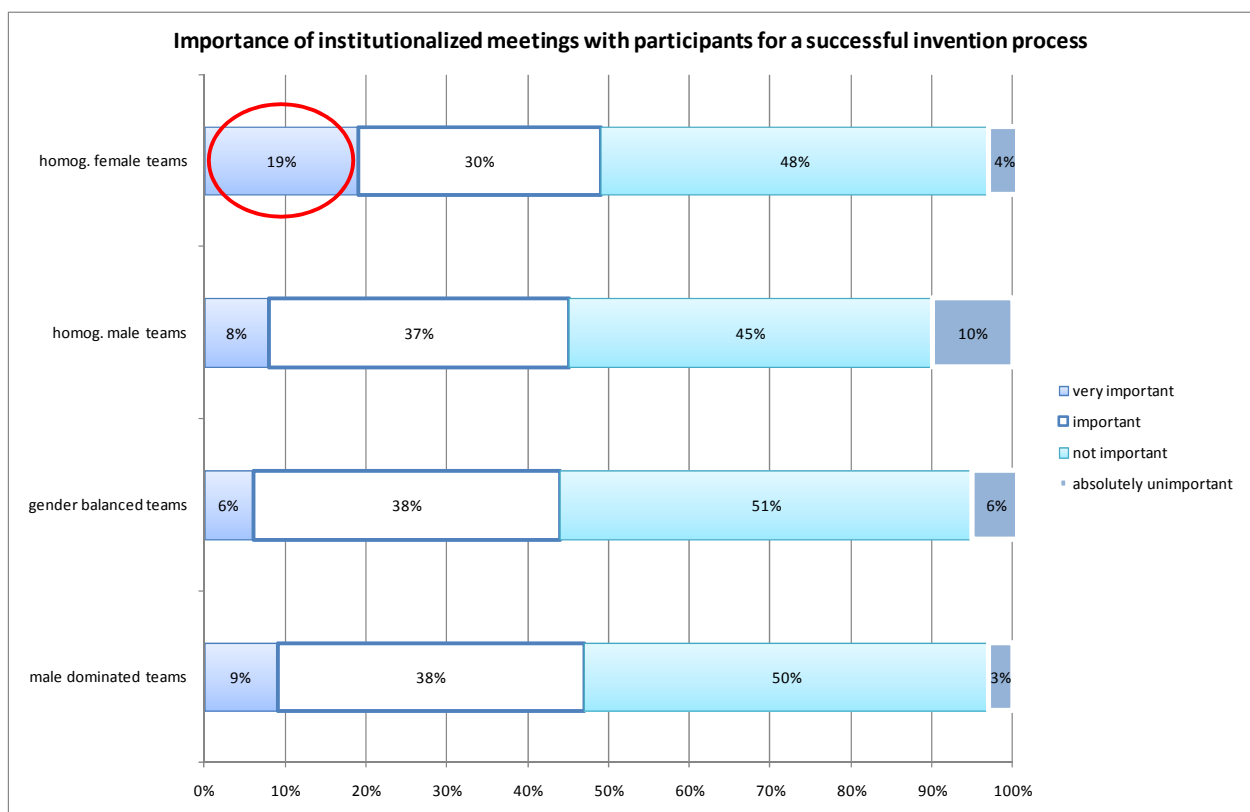


Fig. 4. Importance of institutionalized meetings, 100% corresponds to all interviewees of the respective subgroup

In our online survey, the number of men having children differs strongly from the number of children women have: while approximately half the female researchers have no children, 58% of the male researchers have 2-3 children. The question arises: do women drop out of the innovation process as soon as they become mother or do they remain childless for some reason or another. A glance at the child care situation described by the respondents of our online survey shows that 67% of the female scientists take/took parental leave, work part-time/in the Home Office while only 5% of the male scientists do so. Another important result in this context is the fact that 43% of the female researchers state that child care has a great influence on their innovativeness whereas only 13% of the male researchers feel this way.

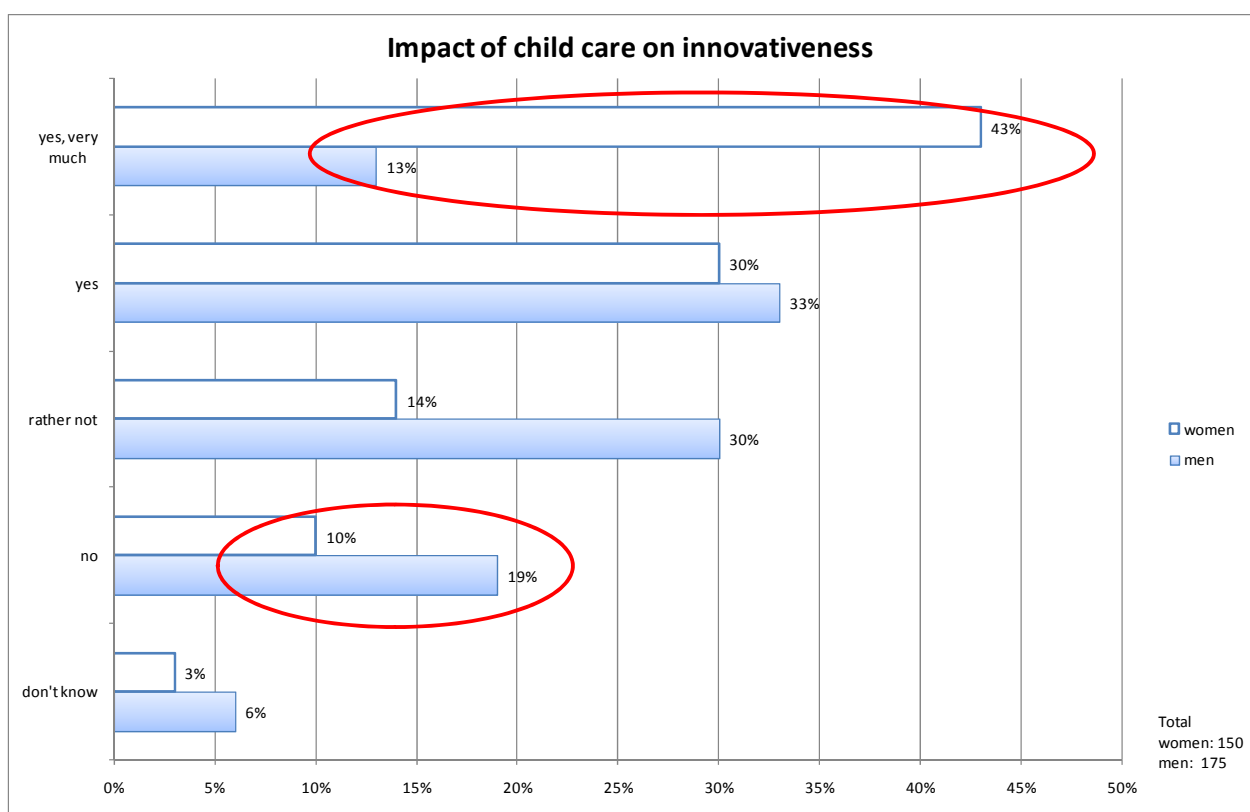


Fig. 5. Impact of child care on the researcher's innovativeness

6. Conclusion and outlook

The results of our study show that in the current innovation environment within the R&D industry, organizations suffer from the lack of sustainability in their knowledge pool. Highly skilled workforces, mainly the female inventors, do not perform to the best of their innovative potential.

The suboptimal support in the area of child care reveals a direct effect on the inventors' innovativeness, especially for female researchers. It creates pressure, whereas this energy could be directed into innovative power provided the organization offered a higher support for childcare. In some cases, it was stated that both, family life and a professional career as a researcher, could not be combined due to inflexibility of the organization or lack of daycare. Several (female) researchers decided to completely drop out of the innovation environment and sought positions in marketing or public relations that were expected to easier allow work-life balance. As a consequence, the knowledge of these highly qualified researchers has left the organization's knowledge pool irretrievably.

Part-time work is offered by several organizations and undoubtedly a successful tool to encourage the integration of highly-qualified female researchers into the organization during parental leave and to prevent them from resigning. However, part-time work reduces the working hours of the female researchers and thereby the period of time that can be used for inventions as well as their participation in networking that are important with regard to knowledge transfer and knowledge generation.

What can an organization do to improve the tapping of their knowledge pool? First of all, management needs to raise an awareness of the importance of a sustainable knowledge pool within an organization. The knowledge that researchers acquired over years during their professional career clearly represents one of the organization's greatest assets. If a researcher leaves the organization or is not able to perform according to his or her optimal level, his or her knowledge leaves the organizational knowledge pool. Oftentimes, leaving the organization is regarded as inevitable by female researchers, when they enter the family phase. Hence, measures such as support for child daycare and flexible work time regulations offered by the organization help the inventors to stay within the organization and focus on their actual research. It is therefore a key to build an organization that understands the needs of its employees and actively sets measures that support the inventors in managing their work-life balance in order to retain the researchers, their knowledge and a sustainable knowledge pool in the organization.

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The technological advancement of our civilization has created a consumer society expanding faster than the planet's resources allow, with our resource and energy needs rising exponentially in the past century. Securing the future of the human race will require an improved understanding of the environment as well as of technological solutions, mindsets and behaviors in line with modes of development that the ecosphere of our planet can support. Sustainable development offers an approach that would be practical to fuse with the managerial strategies and assessment tools for policy and decision makers at the regional planning level.

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