Knowledge Work in Campus Environment

Opportunities of New Technologies in Working and Learning Spaces

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Abstract

Learning and research environments in academic campus context are undergoing fast changes. The changes are occurring both on the level of technology implemented to the environment and the space itself as the traditional cellular offices are increasingly being replaced by open work environments. Knowledge workers, such as the researchers, are at the core of creativity and innovation. The ideal working and learning environments support both creative thinking and collaborative interaction. This article explores the current understanding of the requirements of high quality research and learning environments, and it aims to examine the link between creativity and space. In doing so, I wish to highlight how the architecture of the workspace can respond to the requirements of a successful working environment and how immaterial elements, such as lighting for instance, can induce creative thought, achievement, and innovation and importantly enhance the well-being of the occupants of the space. Furthermore, I will look into how the architecture and technology of the space affect the dissemination of tacit and explicit knowledge amongst individuals and within groups. As part of my research project, aimed to provide new scientific information of the real user needs in academic working and learning environments and create concepts of hybrid multi-spaces, I will discuss in this paper how architecture and lighting design can support knowledge sharing, peer-to-peer interactions, creativity and innovation, which are imperative for success in knowledge work. Hence, the findings could inform the design of new learning and working environments suitable for both user expectations and knowledge production.

The current change in academic environments

Researchers, teachers and students will be progressively more mobile, networked and have increasing access into various technological and virtual applications and networks in the future. New academic workspaces, such as learning and research environments, are evolving with fast pace. The changes require adjusting from both physical spaces and their occupants. The motives for the change are many and they range from the need to reduce the financial costs and buildings' carbon imprint to the change in users' habits of gathering and disseminating information through the new technologies (den Heijer & den Heijer 2011). Finnish campus areas, such as the main campus of University of Oulu, were designed in 1960's according to structuralistic design principles. In the core of the University of Oulu main campus are its liveliest public areas whereas the spaces for research are located in peripheral structures of campus building. Structuralistic principles of the architecture enable campus to respond to changes over time. In Oulu the borders between neighboring departments were intentionally dissipated to promote interdisciplinary collaboration in research. Also, the original layout takes into account the changeability of the office layout, which can be utilized in the future changes to meet the contemporary needs. (Salo & Lackman 1998) According to Kampusvisio 2040 survey, the various workspaces of University of Oulu are aging and in need of restructuring (2013). The spaces are old-fashioned and inept to meet the

requirements of new technologies, which are fast becoming an important part or even a necessity for collaborative research work in addition to learning and teaching. Although new types of spaces are being constructed in Finnish campus environments, they are often designed based on what is being built elsewhere or through participatory processes where users design the space themselves (Kampusvisio 2040). At the same time, libraries are changing from places of silent information into collaborative learning environments (Graham 2012, Turner *et al.* 2013). Media Lounge project in the Oulu School of Architecture library is a good example of such change. Briefly, through a competition targeted for students of architecture, the bookshelves and other furniture of the library were reorganized and the lounge area was supplemented with workstations, comfortable furniture and projector. In addition and importantly, both students and staff were given free access to the library around the clock. The library, which was previously under-used, has now tripled its utilization rate and has become an active place of individual working, collaborative working and place of teaching (Lappinen 2013a, Lappinen 2013b). Campus architecture provides exciting features concerning various aspects of knowledge work, learning and the spaces where it all occurs.

Creativity and knowledge work

Sharing the knowledge and transferring it on peer-to-peer level is considered essential for generating creative ideas and turning them into successful innovations and implementations (Davenport *et al.* 2002, Heerwagen *et al.* 2004). Many organizations perceive that the knowledge, which resides within people, as their competitive advantage amongst other organizations over the knowledge, which is uploaded into their web pages or the IT systems (Aznavoorian & Doherty 2011). Indeed, it is important to notice that the knowledge inside people differs from the computer stored knowledge. In essence, knowledge can be divided into explicit and tacit knowledge. Explicit knowledge alone is information that can be expressed in words and numbers and transmitted between individuals readily and systematically in the suitable form of data. Tacit knowledge, also referred to as implicit knowledge, however, is highly personal and challenging to communicate with the others as it is difficult to visualize and express. In the organizational context the tacit knowledge can be technical 'know-how', informal personal skills or cognitive knowledge of beliefs, ideals and values (Nonaka & Konno 1998).

The term knowledge work has been defined to describe the work that occurs primarily through mental processes instead of physical labor. Knowledge work tasks can vary from high-level cognitive work such as planning, analyzing, interpreting, developing, creating products, processing information or ideas to mundane tasks, such as storing and retrieving information and communication (Heerwagen *et al.* 2004). Creativity is often defined to involve the development of novel product, idea, or a problem solution that is valuable to the individual or a larger social group. Also, it has been proposed that creativity has different levels. Eminent creativity is relatively rare and the products of it have a major impact on other. Everyday creativity is daily problem solving and individual's ability to adapt to change. Construction of personal knowledge and understanding is also defined as a creative process (Hennessey & Amabile 2010). Innovation, subsequently, can be defined as the successful implementation of creative ideas (Hennessey & Amabile 2010). The number and frequency of creative ideas and innovation can be seen as the outcome of knowledge work. However, the means and outcome of performance improvement within a group of knowledge workers are less direct than that in factory production or physical labor, for example, and therefore hard to define. The performance of knowledge workers and knowledge-based organizations are affected by management and organization, information technology and workplace design (Davenport *et al.* 2002). Even though enhancing the performance of knowledge work by any standard is challenging, the management and the designers can greatly influence to the work environment in such a way that it does not hinder creative thinking process and problem solving. Understanding the requirements of workspace for creative thinking and collaboration gives designers more tools to aid the workspace design process in such a way that the end result might indeed enhance creative performance.

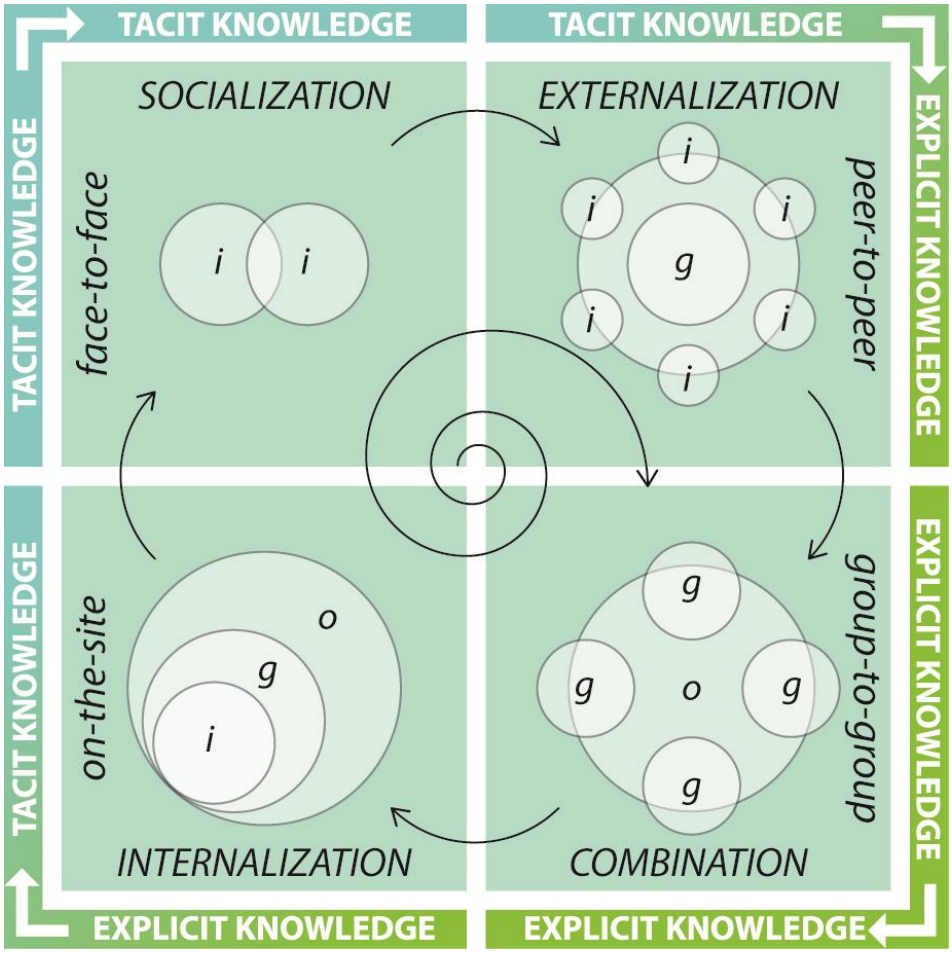

Figure 1. Knowledge conversion in 'Ba'. New knowledge is created in cyclic process of transferring tacit and excplicit knowledge between co-workers and groups. Different levels in organization are depicted in the diagram as individual (i), group (g) and organization (o). The diagram is modified from Nonnaka & Konno (1998).

Place and space of knowledge

In architecture *place* refers to *spaces*, which have been given meaning by their users (Tuan 1977, Nordberg-Schultz 1980). It has been proposed that the physical working space can also be seen as an implicit knowledge medium. When it supports listening, sharing, presenting and comprehending the knowledge it supports the knowledge through space and importantly through people (Aznavoorian & Doherty 2011). Organizational theorists and knowledge management experts Nonaka and Konno (1998) have explored place of knowledge creation through the concept of '*Ba*', a concept originally developed by a Japanese philosopher Kitaro Nishida. Nonaka and Konno use the concept of '*Ba'* to define the 'place' of knowledge creation (Nonaka & Konno 1998). Instead of physical space, the '*Ba*' as a place of knowledge can emerge in individuals, teams, working groups but also during temporary meetings and encounters.

In Nonaka's and Konno's model individual has to get involved and surpass one's own limited perspective or boundary to explore others' rationality and intuition to participate in a '*Ba*'. New knowledge is created through a cyclical process transforming tacit knowledge into explicit knowledge and back to tacit knowledge through following steps: *socialization*, *externalization*, *combination* and *internalization,* which are presented schematically in Fig. 1. During socialization, the tacit knowledge is transferred from one individual to another. Socialization requires physical proximity and interaction. Externalization of knowledge from individuals to group requires articulation and translation of tacit knowledge into explicit knowledge, thus making it understandable and comprehensible by using words, concepts, figurative language and visual aids. Combination of knowledge involves communication, dissemination and systemization of knowledge, the knowledge is spread among organizational members and also disseminated through presentations or meetings. Finally,

newly created explicit knowledge is converted into tacit knowledge in both individual and organizational level, thus embodied into action and practice. (Nonaka & Konno 1998)

In their research Dul *et al.* (2011) discovered that even though both social-organizational work environment and physical work environment independently affect creative performance, the creative character of individual has the most significant effect on creative work performance. The social-organizational work environment can be thought to consist of factors such as challenging job, teamwork, task rotation, autonomy in job, coaching supervisor, time for thinking, creative goals, and recognition of creative ideas and incentives for creative results. These elements are immaterial as opposed to the elements that make the physical work environment, such as furniture, indoor plants and flowers, calming colors, inspiring colors, privacy, window view to nature, any window views, quantity of light, daylight, indoor climate (temperature, humidity, composition of air), sounds and odors (Dul *et al.* 2011). Interestingly, Dul *et al.* also found out that the creative performance of individuals with high creative personality benefitted more from the positive effects of physical environment. Therefore creativity supporting environment might have indirect effect also on the individuals with low creative personality, as they have been shown to benefit from the presences of more creative coworkers, thus implying the importance of interaction amongst the coworkers (Dul *et al.* 2011).

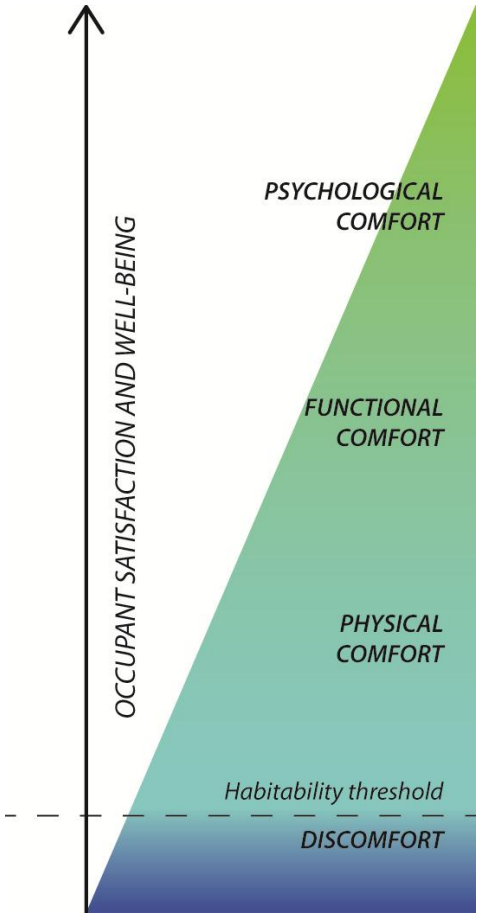

Figure 2. Environmental comfort model. Occupants' satisfaction and well-being can be divided to different levels of comfort – physical, functional and psychological comfort. Diagram modified from Vischer (2008).

Physical and psychological well-being in work environment

Certain indoor building conditions can increase or decrease the well-being of its occupants in relation to health and comfort. When occupants are exposed daily to stressors, for example unsuitable thermal conditions, poor lighting, moisture, mold or noise and vibration, the short-term and long-term effects may cause building related illness. Occupants' physical and mental ability to cope with environmental stressors affect their behavior and responses, which in turn affect their individual and collaborative performance (Bluyssen *et al.* 2011).

Vischer (2008) has developed an environmental comfort model of workspace quality presented in Fig. 2. Physical comfort has to be met to make the environment habitable. Fundamentally, environment has to meet the basic needs of safety, hygiene and accessibility, otherwise the building is uninhabitable. Furthermore, building has to meet the needs of functional comfort, such as appropriate lighting, ergonomic furniture and spaces available for meetings and collaborative work. The importance of functional comfort arises when the ability of occupants to conserve their attention and energy for their tasks is considered, as opposed to expending it to cope with adverse environmental conditions. The third level of comfort in work environments is psychological comfort. This level links psychosocial aspects of the worker with the environmental design and management of workspace through territoriality, privacy and environmental control. (Vischer 2008)

Quality of lighting in working and learning environments

Recent advances in lighting technology have made it an important topic to discuss in relation to design of work environment. The quality of light is one of the factors that contribute to the good quality indoor environment and it has been shown to effect on health, productivity, well-being and alertness levels, for instance. Recommendations for average illuminance level range from 300 lux (reception, filing, copying) to 750 lux (technical drawing) (Van Bommel & Van den Beld 2004). The recommendation for general office work is 500 lux. This involves tasks such as writing, copying, reading, and data processing. In addition, the same 500 lux is recommended also for conference and meeting rooms (Van Bommel & Van den Beld 2004). Interestingly, lighting can affect positively on mood and work performance of the users' of the space though increased aesthetic appreciation of the space. Consequently, this increases occupants' engagement to the work (Veitch *et al.* 2013). This is in line with Vischer's statement that elements, which increase functional comfort and psychological comfort enhance work engagement and performance (Vischer 2008). This brings added value to the lighting and raises its importance above

mere physical comfort. Veitch *et al.* propose in their model that when lighting conditions meet individuals' preferences, the room appearance will be more favorably judged. This in turn will influence pleasure and workplace satisfaction, leading to positive effect on environmental satisfaction and productivity. The pleasure effect of favorable lighting also affects work structure, complex cognitive appraisal and motivation through work engagement (Veitch *et al.* 2013). Human beings have an inherent desire for daylight and it is associated with healthy indoor environments. Expectedly, people have a strong preference for windows in their working environments and it is believed that windows improve working productivity (Leslie 2003). The flow of natural daylight through the windows contributes positively to a good working environment due to its dynamic nature, varying in both color and intensity. The dynamic changes in daylight have a positive influence on mood and stimulation (Van Bommel & Van den Beld 2004).

When tested, the productivity of a moderately difficult visual task in metal-working industry increased by 8% or 20% as light intensity was improved from 300 lux to 500 lux or to 2000 lux, respectively. Also, number or errors and accidents were reduced when lighting conditions were improved (Van Bommel & Van den Beld 2004). Similarly, higher luminance levels have been shown to induce alertness of office workers (Smolders *et al.* 2012) and to increase students' concentration in classroom settings (Sleegers *et al.* 2013). The study employed for office workers tested effects of 200 lux or 1000 lux at eye level. When subjects were exposed to higher luminance for one hour during morning period, participants felt less sleepy and more energetic and were more inclined to show faster reaction on psychomotor vigilance tasks and increased physiological arousal, e.g. increased heart rate (De Kort & Smolders 2010). These studies leave room for more analysis and testing, as the lighting levels were either below or significantly above the 500 lux suggested for working environment and do not reveal the desired luminance level of the actual occupants of tested environments.

In addition to luminance levels, the correlated color temperature of white light is also important. Shamsul et al. (2013) have measured higher alertness and better performance levels in static artificial daylight conditions (6500 K). However, neutral cool white (4000 K) light was preferred over artificial day light (6500 K) and warm white light (3000 K) conditions by many of the respondents in the study and considered better for visual comfort and more suitable for longer periods of working (Shamsul *et al.* 2013). On the other hand, when work environments and lighting is considered, designers of creative environments should also be aware that brightly illuminated environment increases self-awareness whereas darkness and dim environment increases creativity. Furthermore, the direction of light appears to play a role on how light mediated visual messages effect on creativity (Steidle & Werth 2013a, Steidle & Werth 2013b).

Intelligent and adaptive lighting in working environment

Lighting technology has advanced with fast pace during last few years, especially due the fast development of LED lighting. The new intelligent and adaptive lighting technologies provide opportunities to create more functional lighting that is interactive with both users and occurring lighting conditions, e.g. natural daylight. Use of adaptive lighting applications in office environments can create 50 % energy savings and thus are an important part of sustainable design (Descottes & Ramos 2013, Yun *et al.* 2012). Because dynamic and adaptive lighting techniques are new and have only been available for relatively short time, therefore the effects of their use in either working or learning environments have not been studied to great detail. However, initial field studies do show positive effects of dynamic lighting for well-being and performance over static light, in a setting where changes of intensity and color temperature have been applied in such a manner that it offers higher illuminance and color temperature in the morning and after lunch time, and lower illuminance with warmer white light during the late morning and afternoon (De Kort & Smolders 2010).

As mentioned earlier, the lighting recommendations to most of the office workspaces are 500 lux. When lighting is constructed according to recommendations, the setting leaves no room for personal adjustment (Van Bommel & Van den Beld 2004). This is a limitative factor, as individually controlled lighting conditions are considered more comfortable than conventional fixed conditions. Interestingly, availability of individual control over lighting conditions during the workday seems to increase resilience to fatigue when compared to working in environment without control over luminance levels (Veitch *et al.* 2013). In open-plan offices and environments that are occupied by multiple persons, the controlling of dynamic changes generates challenges. The dynamic changes can be set to occur to the entire area, different zones or separate workstations. Individual preferences and different tasks set dissimilar needs of lighting in different areas of work environment. Whereas workstation specific lighting is important to visual performance of the ongoing task, the illumination of surrounding area affects the ambience of the environment. To provide truly personalized lighting conditions and workstation specific lighting, individual luminaires need to be actuated individually at different levels. As the end result energy saving are generated from adjusting the light levels to users' needs. Also, the unoccupied areas remain unlit or minimally lit. However, when individually adjustable or adapted systems are designed, it should be taken into consideration that nearby luminaires add to the illumination levels and thus lighting configurations needs to be designed to take the cumulative illumination into account (Wen & Agogino 2011). By deploying the workstation with light sensing devices, such as photosensors, the illumination provided by artificial lighting can be adapted to provide desired lighting levels together with daylight. Using occupancy sensors, the illumination can be dimmed or turned off when workstation or entire office is vacant (Wen & Agogino 2010). Up till now the lighting design is an important area of workplace design that has been generally disregarded. Even though the positive effect of natural daylight has been acknowledged (Leslie 2003) and initial tests have shown that dynamic changes and color temperature of light matter (De Kort & Smolders 2010, Shamsul *et al.* 2013), the advantages of state-of-the-art technologies provide opportunities that have not yet been taken advantage of to influence work environment positively.

Collaborative work environments

Carefully designed working environment attracts users and provides sufficiently stimulating but distraction-free environment. Innovation enhancing environment is pleasant and comfortable (Haynes 2008). Collaborative work as such can be defined as working together at its simplest. However, good collaborative work entails both focused individual tasks and interactive group work (Heerwagen *et al.* 2004). The collaborative working environment must thus support both individual focus and group interaction, while also facilitating transitions between these activities. An environment that supports collaborative working enables users to be aware of what is happening in the surrounding environment. The environment has to enable brief, opportunistic encounters and to provide spaces within the work environment for collaboration (Heerwagen *et al.* 2004). The new generation of working and learning environments will benefit from new technologies, such as adaptive lighting (De Kort & Smolders 2010, Shamsul *et al.* 2013), which will improve the functional comfort of the used space as was discussed in previous chapters. Furthermore, new pervasive technologies will affect knowledge work in future. Various mobile devices will be increasingly common in work environment and to enable knowledge sharing new applications such as distributed user interfaces will enable knowledge sharing in novel ways (Fisher *et al.* 2014). These will be discuused shortly. New technologies will encourage knowledge sharing and peer-to-peer collaboration either through face-to-face interaction or through virtual space (Aznavoorian & Doherty 2011, Fisher *et al.* 2014).

The workspaces assigned for researchers and teachers range from single or multi-occupancy cellular offices to open-plan and non-territorial offices in academic environment (Pinder *et al.* 2009). Placing a typical academic worker into a single workspace typology is difficult as academic workers often need to take multiple roles during their workday. Academic workers need to switch

between being a lecturer, researcher, tutor and administrator and thus the traditional single-occupancy cellular office has been considered an ideal academic work environment in terms of providing privacy for both concentration requiring tasks and noise generating activities. However, many higher education institutions are moving towards proving more open, shared environment to increase knowledge flow and collaborative working (Pinder *et al.* 2009). It has been proposed that the layout of the work environment increases interaction and thus knowledge sharing in two ways: through peoples' movement and through their co-presence (Rashid *et al.* 2005). Fundamentally, academic knowledge workers need privacy to think, to analyze and to reflect in order to internalize knowledge and oppositely interaction and collaboration with other workers to externalize the knowledge in order to generate and evaluate ideas (Heerwagen *et al.* 2004, van Sprang 2012).

Although open environments do provide opportunities for chance encounters and makes it easier to initiate interaction with colleagues, lack of privacy or the need to find private space for longer discussions may generate negative effects (Pinder *et al.* 2009). The multi-space typology created by Boutellier et al. (2008) was developed to enhance knowledge transfer in research environment. The advantage of multi-space is that it offers diverse space and places for different kind of working, such as quiet rooms, teamwork spaces, break areas and meeting rooms. Consequently, users have the opportunity to withdraw into quiet areas for high-concentration tasks or alternatively feel free to collaborate and discuss without disturbing others (Boutellier *et al.* 2008). This changes communication landscape drastically when compared to cellular offices, which is the traditional workspace based on the occupant's privacy. The multi-space layout of the office enhanced communication between co-workers. Interestingly, the communication events were quicker than previously. Boutellier et al. suggest that this is due to people in multi-space share the same '*Ba*', the feed-back and knowledge exchange in the cyclical process of *socialization*, *externalization*, *combination* and *internalization* is faster and sharing of tacit knowledge is improved (Nonaka & Konno 1998, Boutellier *et al.* 2008). In their analysis of a case study, Zoller and Boutellier (2013) propose that weak ties created in an interdisciplinary multi-space office environment enhances inspiration and creative thinking thus improving early stages of discovery. Subsequently, during the later stages of product development the stronger ties enhance tacit knowledge transfer in a more dedicated workspace devoted for teamwork (Zoller & Boutellier 2013). However, it is difficult to create such a work environment that would meet all the requirements for individuals and work tasks. Computer work and concentration work require peace and absence of visual and acoustic distraction. In contrast informal and formal meetings require building layout that support chance encounters, transparency in design and freedom to communicate and interact (van Sprang 2012).

It is important to take into account that workers who are moved out of private enclosed offices into open workstations may not feel comfortable about the change. They may judge their environment more negatively and feel that the open office environment creates lack of privacy, acoustic problems and decrease in confidentiality (Vischer 2008). It is therefore imperative to take these aspects into account while new working environments are designed. Co-participatory design process might enforce occupants' ownership and feeling of belonging to their working environment and also reveal valuable information of actual needs for designers.

Interactive technology enriched collaboration space

Collaborative workspaces can be enhanced with interactive technologies. These technologically enhanced spaces can be used to solve problems and make decision collaboratively. The technologies used in these spaces are generally screens in various sizes that enable communication and knowledge sharing with participants of the meeting (Issa *et al.* 2006). The enhanced technology can be used to support information communication and sharing (sharing context), to interpret and make recommendations (analysis context), to facilitate collaborative setting (interactive context) and to enable capture of information (documentation context) (Issa *et al.* 2006). One of the emerging research fields related to knowledge sharing and collaborative work is

distributed user interfaces or DUIs. In this kind of user interface architecture components of knowledge or other material are distributed across different hardware devices in space and time. The mobile devices are used increasingly in learning and working environments. Fisher *et al.* (2014) have envisioned following scenarios for the use multiple devices with distributed user interfaces: A display wall of multiple screens and multiple computers interacting with digital media which spans on all of the displays; an output device displaying content located on another computer on the network; and two or more mobile devices rendering the same content that are placed side by side to form a larger picture spinning on all of the displays. One can also envision a situation where information is transferred from private device to a shared public display. Although these technologies have several issues to overcome, they will provide useful tools for peer-to-peer communication (Fisher *et al.* 2014).

Creative and collaborative learning spaces in technology-rich campus environment

In addition to research, campus environment is also a place for teaching and learning. The internalization and externalization of knowledge are at the core of learning, teaching and research, thus these environments share similar requirements. The learning spaces are also evolving. This is happening partially due to same reasons as development of work spaces. For instance, due to changes in technology but also due to changes in pedagogics and expectations from students. Consequently, a good contemporary learning space is a fusion of technology, space and pedagogics (Graham 2012). Libraries are traditional learning spaces for students in higher education institutions. However, the roles of libraries are changing into collaborative learning environments where users meet to share materials and to learn new skills. Similarly to working environment, the space surrounding the student may have an impact on learning. The physical settings of space may carry an unspoken message of silence but it can also encourage exploration, collaboration and discussion (Graham 2012, Turner *et al.* 2013). Creative learning spaces are designed with a focus to increase students' engagement with the learning process and their motivation to explore, to experience and to discover. The characteristics that make the creative spaces attractive for users are the aesthetics and unique atmosphere of the space, e.g. the architectural features of the space. In addition, these spaces offer a range of uses and facilitate group discussion, seminars, team works and training sessions (Jankowska & Atlay 2008).

The term next generation learning space defines a new type of classroom, which incorporates both physical and virtual space. The digital technologies enable users to access a wider range of communication and information that can be incorporated into the learning process. In the design of such spaces additional focus has also been paid for the design of the spaces making them more flexible, thus enabling more individualized learning opportunities for students (Wilson & Randall 2012). The digital technologies are vastly embedded in our environment outside the learning spaces and we need them for current working methods. However, architects and designers generally have little knowledge of latest information technologies or the field of interaction design (McCullough 2005). Although new technology-rich environments do offer interesting possibilities, they also create challenges for both the users and the designers of workspaces. It is imperative to research new solutions for workspaces, evaluate the real needs and the user experiences of existing contemporary typologies of working and learning environments and to disseminate the gained knowledge and understanding for the designers of workspaces in and out of campus environments.

Conclusions

Design process of novel working and learning environments requires understanding of particular circumstances of multi-space, users and their working habits. Certain principles need to be obvious for both designers and users – the actual needs of the multi-space users and the values the community is trying to achieve through reshaping the work environment. The designer should be able to recognize what are the desired roles and the intended uses of

the multi-space. Also, the ability to anticipate the situations in which users will find the new implementations valuable or alternatively, difficult to adjust to, is important. In understanding the novel needs for such environments, the development, research and design processes should be interactive and iterative. Importantly, the user experiences of newly built environments should be evaluated and taken into account on the next stage of development. Specific strategic goals have been used in the design process of some established cases of new academic workspaces. In one case study the workspaces were designed to stimulate creativity and adventure in research processes and in another case study inter-disciplinary research was encouraged and supported through design (Pinder *et al.* 2009). To elucidate the necessary factors to create such environments, we need to be able to identify the key behaviors and activities associated with individual and collaborative knowledge work and to assess how the physical environment influences these activities and behaviors (Heerwagen *et al.* 2004).

Future working and learning environments should provide opportunities for sharing information from both mobile and local technologies used in the space. When sharing of the explicit knowledge occurs in face-to-face situation the shared information is enriched with tacit knowledge (Heerwagen *et al.* 2004, Nonaka & Konno 1998). Current technologies allow sharing the files between devices. It is apparent that the current protocols allow sharing data files via various networks, but as distributed user interfaces are under fast evolution (Fisher *et al.* 2014), designers have now the opportunity to challenge the form and the place of devices that could be used in peer-to-peer knowledge sharing.

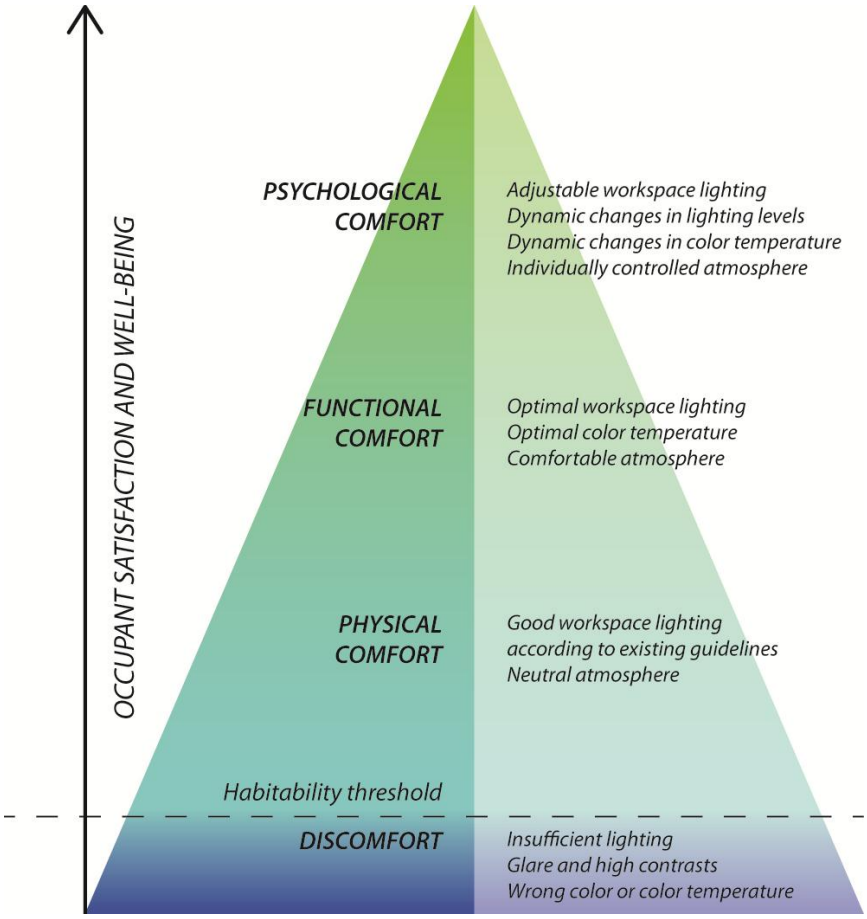

Figure 3. Environmental comfort model adapted to workspace lighting. Good quality lighting affects positively on physical, functional and psychological comfort of workspace. Even though optimal lighting conditions can be achieved with static settings, individually controlled lighting with dynamic changes may provide novel opportunities to enhance occupants' well-being.

Good lighting conditions are imperative in providing high quality working and learning environment. Fig.3. presents various elements of lighting placed in the modified environmental comfort model developed by Vischer (2008), which was discussed earlier. Additionally, lighting has fundamental effect on the atmosphere of the space. Up-to-date lighting technologies provide advantages

that are aesthetic, functional and sustainable (Yun *et al.* 2012, Wen & Agogino 2011, Wen & Agogino 2010). Careful design of amount of light, targeting and color temperature enable creating a high quality working environment with the benefits of increased functional and psychological comfort and increased well-being and performance (Veitch *et al.* 2013, Smolders *et al.* 2012, De Kort & Smolders 2010, Shamsul *et al.* 2013). Sensory technology provides opportunities to use intelligent lighting that adapts the lighting conditions to meet the requirements of occurring or pre-defined scenarios. Intelligent lighting system can distinguish different users and adjust lighting environment locally to meet the diverse needs in shared space. Because the intelligent and adaptive lighting techniques are new and have only been available for relatively short time, their effects in either working or learning environments have not been studied to great detail. These techniques provide possibilities for dynamic changes in lighting, which can be expressed in changes of lighting intensity, color or color temperature of white light. Because our visual sense is more sensitive to the changes in light rather than the absolute luminance itself (Ehlert 2009), it is important to assess which kind of dynamic and adaptive lighting is suitable in working and learning environment and how it can be utilized to bring added value to the functionality of the space.

Carefully designed space attracts users and provides sufficiently stimulating but distraction-free environment. Innovation enhancing environment is pleasant and comfortable and enhances both organizational performance in the long run but importantly, it provides a good quality environment for its occupants thus enhancing their creativity, innovation and well-being.

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