Collaboration Space for Creative Knowledge Work – Analysis of Industrial Pilots

Mika P. Nieminen, Mikael Runonen, Mari Tyllinen, and Marko Nieminen

Aalto University School of Science
Department of Computer Science and Engineering
P.O. Box 15400, FI-00076 Aalto, Finland
{firstname.lastname}@aalto.fi

Abstract. In this paper we describe our experiences piloting a collaboration space DiWa that supports creative group-based knowledge work. The developed prototypes of the system were piloted at three industry and public sector partners in Finland conducting product development and city zoning and at one research institute involved in service design in Beijing, China. The system design was based on extensive literature review, observations and interviews at the partners. The results presented in this paper are derived from four one month long pilots using the DiWa prototype that were studied using observations, interviews and questionnaires. Main results are the observed differences in the use of collaborative spaces and work practices between the Finnish users and their Chinese counterparts. The paper concludes with eight recommendations for the design of collaboration spaces.

Keywords: Collocated collaboration, interactive spaces, supporting knowledge work, cultural differences.

1 Introduction

This paper describes our experiences and results from a set of month-long industrial pilots using the developed DiWa collaboration space. DiWa space incorporates parallel use of large displays to enable fluent information sharing during collocated collaborative tasks. Earlier systems with similar technology of features, lately also known as blended spaces [1], include dedicated ubiquitous group work facilities with large visual displays [2], combining digital and analog tools to support meetings [3] and use of large multi-display arrays and multi-user interactions [4].

In the DiWa space separate computers are connected to each other using a shared document repository, implemented using a network attached server, and a specially developed communication protocol based on pragmatic multicast [5]. Some of the computers are desktops with large touchscreen displays located permanently in the DiWa space (shown in figure 1) and some are laptops carried into the facility by users. They all can be connected to each other to form a single collaboration system by installing a small control application (depicted in figure 2) that resides on the top of each screen providing necessary means to control and share files to other desktops.

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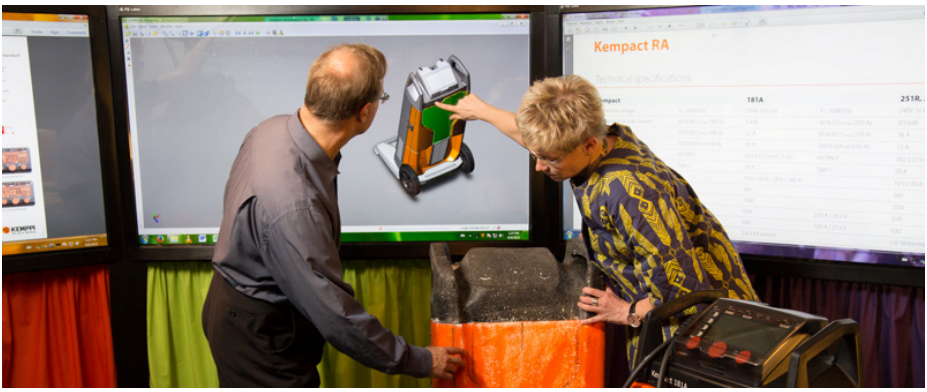

Fig. 1. DiWa collaboration space used for a product review

The DiWa space also includes advanced memory support functionalities (described in detail in [6] and [7]) that allow the collaborators to mark important events. Event marking automatically saves the contents of the attached displays and a voice recording surrounding the event. A visualized timeline of all project activities, including marked events, accessed files and the times of collaboration sessions enables users to easily return to them.

Fig. 2. The user interface of the DiWa Control Service with open event menu

1.1 User-Centered Design Process for a Group Work Space

The applied User-Centered Design (UCD) process consisted of a systematic literature review, observations at actual context of use, interviews with relevant stakeholders, iterative development of a collaboration space prototype and piloting it at the premises of our industry and public sector partners.

Literature review. A systematic literature review of 49 search terms to five sources delivered 13.6 million hits. 907 articles were individually browsed of which 168 summaries were written. Based on the summaries the collected articles were grouped into eight categories: Group Work, Work Practices, Space Design, System Design, Interaction, Requirements, System Possibilities and Video [8].

Requirements Elicitation. During a field study we observed 12 collaborative situations and interviewed 22 participants. In combination with the literature review this produced 82 individual requirements for an interactive collaborative space. Main findings include collaboration, support of conventional work practices, parallel and uninterrupted use and physical properties of a collaboration space. [8]

Action Research and Prototypes. The development of the DiWa prototype was scheduled to three six months periods. In the beginning the prototype development was solely guided by the original system requirements, even though our partners were invited to review the first concept demonstrators in fully facilitated group sessions. In the second phase the initial prototype version was tested internally. The usage was mainly by university students and researcher on an invitation only basis. In the final phase included the full scale pilots at our partners described in the next section.

The development was based on participatory action research approach [9] were iterative prototyping always introduces a new intervention that tries seamlessly to build on top of the previous encounters. This was particularly evident during the consecutive pilots, where every pilot case received an updated version of the prototype with increased maturity, as also shown by the SUS study in the results section.

2 Industrial Pilots

In the pilots the collaboration space was taken to the field and used for real work activities at the participating companies and organizations. A similar collaboration system was also built at a research institute in China to learn about potential cultural differences in the use, utility and acceptance of our solution. The pilot locations in chronological order were:

1. Kemppi, a manufacturer of arc welding equipment. Pilot site was situated in Lahti, Finland.
2. Konecranes, a manufacturer of industrial lifting equipment. Pilot site was situated in Hyvinkää, Finland.
3. City of Vantaa: City planning and zoning. Pilot site was situated in Vantaa, Finland.
4. Beijing Research Center of Urban Systems Engineering. Research institute specializing in elderly care service design. Pilot site was situated in Beijing, China.

All pilots shared a common blueprint. For each site, the system was assembled in an appointed space. Once the system was up and running, an introductory session was given to all future users of the DiWa Space. This session was meant to both inform

the users about the pilot procedure and to motivate them to use the system by communicating its potential benefits. After the introduction, the system was available for use in the partner organization for 4-6 weeks.

One condition was set for all new users of the DiWa Space. Before starting to use the facility, the users were asked to fill out a pre-use questionnaire. This questionnaire included both closed-ended and open-ended questions regarding their experiences in group work and dedicated group work spaces, expectations towards using DiWa and practices of taking and making use of notes.

For the first two pilot sites a researcher observed one team on each of their visits to the DiWa space, while other teams used the facility by themselves after the initial visit. The researcher took the role of a passive observer but switched to active participation when the users required technical assistance or had questions on how to use the system or how to proceed.

Post-use questionnaires and user interviews were conducted at the end of each pilot. A post-use questionnaire was used to validate and compare findings from the pre-use questionnaires and gather additional data about the usage. Enclosed in the questionnaire was also positive/negative System Usability Scale (SUS) [9]. The interviews were semi-structured and considered themes such as experiences of working in the DiWa space in general, usability issues and differences between the DiWa space and other group work facilities that the users were familiar with. The interviews were carried out with great care not to introduce any concepts that were not expressed by the interviewees first. Afterwards the interviews were transcribed as whole. The order between post-use questionnaires and interviews was chosen on the basis of not causing a bias to questionnaire answers by interviewing first.

The same procedure was repeated in the Chinese pilot. However, because none of the researchers were fluent in Mandarin Chinese, some compromises had to be made. Since the pre-use questionnaire was rather straightforward and simple, it could be translated to Chinese by our local partner. The semi-structured interview question framework and post-use questionnaire were more complex and more sensitive to exact tone and necessitated be first written in English by the researchers and then translated to Chinese by a professional translation agency. The interviews were recorded and then transcribed. This operation was reversed for the results, i.e. the interview transcripts and questionnaire results were translated to English also using a translation agency. In order to obtain comparable data, two persons from the Chinese partner were coached to carry out the interviews in Chinese in a similar manner to those conducted in Finland.

3 Analysis

All 17 interview transcripts and open-ended answers from questionnaires were coded according to a predefined scheme by two researchers using ATLAS.ti. The following a priori codes were used:

- **Memory Support.** All statements discussing the memory support functionality of the interactive space or related aspects.

- **Reasons for Returning. S**tatements and reasoning that discussed incidents where users returned to their notes or other materials from a previous meeting.
- **Expectations.** Statements answering questions such as "What users expect the system to be?", "What kind of functionalities it will contain?" and "What kind of changes there will be in their everyday work?". Also expectations towards change in attitudes were included.
- **Realization.** As a reflection of expectations, Realization served as a vehicle for how users experienced the usage of the system in contrast to their expectations. This code did not contain only system-specific observations but also changes in facilities.
- **Opinions and Attitudes towards Group Work.** Opinions and attitudes set the level of how interested users are about group work in general. These codes acted as a filter through which other codes were viewed.
- **Current Situation.** An assessment of work conditions in general. These conditions included current facilities, current practices and current tools.
- **Taking Notes.** Whenever users specified that they took notes of some kind or discussed anything related to such activity.
- **Work Practices.** A collection of newly gained means and practices after using the system and getting familiar with it.
- **Problems.** These could include difficulties with facilities, equipment failures, workflow problems, or alike.
- **System Evaluation.** Similar to Realization with a small difference. Whereas Realization captures experiences vis-à-vis expectations, System evaluation is for statements that contain assessments about system's usability and functionality.
- **General Observations.** A repository of statements that did not fit into any other codes but still carried interesting information.

Most of the codes contained several sub-codes and supplementary grounded sub-codes were added when necessary. Furthermore, passages were coded as negative, neutral or positive according to the tone in which the interviewee presented her notions. This categorizing was only done when the researcher could deduce the tone from the context with certainty.

Once coding was finished, all the codes were revisited by two researchers. The analysis was continued using hybrid card sorting [10], where some of the categories were decided in advance. The first four categories were imported from the original user requirements: user-centric approach, work practices, space design and adaptability. During the sorting new categories emerged: change management, considering the collaboration space as a tool, integration to existing systems and the feasibility of the designed solution. In order to make the categories raised by the qualitative analysis more beneficial, approachable and practical for our project partners, it was considered appropriate to formulate the results as recommendations.

4 Results

In the following subsections we outline the results from our studies and draw comparisons between the Finnish pilots and their Chinese counterpart.

4.1 SUS Study

A SUS study was carried out as part of the post-use questionnaires. The results are shown in table 1. The SUS score for the first Finnish pilot was 54.7 which according to Bangor et al. [11] falls barely into the category of "marginal" or "ok" in adjective ratings. For a system that would be used daily as a tool for a group of designers, such value would be less than desirable. However, we argue that for a prototype system with numerous known technical flaws and missing features, this is acceptable.

As Finnish pilots progressed, the system was developed further and many of the programming errors were fixed. This is reflected with an ascending score between pilots (54.7 | 65.5 | 73.8). For the third pilot the score over 70 can be considered as "acceptable" [11]. However, as the sample size is small whereas the standard deviation is very large, this value should be treated with some reservation.

Even though the system version used in the Chinese pilot was developed the furthest, the SUS score given to it was the lowest. This lower score was possibly caused by misplaced expectations towards the system and some critical errors in the system. Due to the language barrier, the researchers were not able to sufficiently communicate that some functionalities were deliberately left outside the piloted system. The most sought after features not found in the DiWa space were cloning the desktop of a personal laptop to the shared screens and ability to participate to a collaboration session from a remote location. These expectations persisted throughout the pilot. One catastrophic programmatic error in the DiWa system was that documents with Chinese character encoding were not supported. This meant that the Chinese users could not use their files "as is", but they had to rename them when used in the DiWa space.

Table 1. SUS scores for all pilots

Pilot site	N	Score	STDEV	MEDIAN
Finland #1	9	54.7	8.0	
Finland #2	5	65.5	6.0	
Finland #3	2	73.8	33.6	
Finland all	16	60.5	13.1	57.5
China	8	51.6	14.5	
Total	24	57.5	13.1	58.8

4.2 Taking Personal Notes

Reasons for personal note taking and the amount of notes taken were rather similar both in Finland and in China. However, there are clear differences in the note-taking tools and in the ways of taking notes. Finnish users are generally more traditional,

sticking to pen and paper or computers when writing or drawing their notes, while in China also smart phones and digital camera are used often. The use of audio recordings was also significantly more common in China.

Based on the answers, it can be said that in China DiWa had less impact on the practices of taking personal notes than in Finland. In Finland taking personal notes was diminished during the pilots, whereas in China the use of pen and paper increased and the use of smart phones decreased.

The DiWa functionality for marking important events was not commonly used during the pilots. This was observed the same both in Finland and China. The participants in Finland shared several views on the reasons for not using the functionality. The voice recording functionality was seen producing too much information, and there were concerns that event marking would have a negatively effect on the discussions and decision-making. On several occasions the users could see the need for such functionality afterwards, but the novelty of this new practice made it difficult to remember to use it. In China, a clear difference was seen in the attitudes towards recording meetings. Participants hoped to receive full recordings of the meetings and several requests for video recordings were stated.

There were some differences between China and Finland in the ways of returning to previous meetings. Photographs, audio and video recordings were used more in China compared to Finland where these tactics were not generally used. However, the things that participants identified as important about the meetings held in the DiWa space were similar: common memorandums and other collaborative documents were regarded the most important. Chinese respondents wanted to have a full record of everything that happened in a meeting, while the Finnish respondents frowned upon this idea.

4.3 Group Work Practices

The pre-use questionnaire included questions about how beneficial group work is seen and if respondents preferred "working alone" to "working in groups" of different sizes and modes. Somewhat surprisingly, there was no significant difference in answers between Finnish and Chinese respondents relating to group work practices. Finnish and Chinese users alike deemed both informal and formal group work beneficial. However, it is noteworthy that no one regarded working in groups larger than 6 persons the most effective.

When the users were asked to compare the DiWa space to other group work spaces or meeting rooms, there was again no real difference between the Finnish and Chinese responses. According to the aggregate results out of 24 responses on a 5-point scale with a neutral value in the middle, 18 rated the DiWa Space to be more suitable for their activities than other options. 17 regarded it as more pleasant and 14 appreciated the décor more when compared to previously used group work facilities. Ease of use was considered worse by 13, which can be contributed to the technical difficulties encountered with the prototype system. 10 users valued the understandability of functionalities lesser.

5 Recommendations for Designing Collaboration Spaces

Combining the potential benefits of new technology with the best work practices requires adopting multiple perspectives to design and can be quite challenging. Based on our study, we describe here eight recommendations for designing collaboration spaces. These recommendations are specifically targeted for the organizational decision-makers responsible for procurement or development of collaboration systems or facilities for collaboration.

Design for the Users. Designing collaboration spaces requires deep understanding of the workers' existing best practices. These practices can be slightly different for all employees, even within the same unit or department. The collaboration space should not be an arbitrarily placed generic meeting room based on an organizational chart but instead it must be tailored to fit the users, their needs and practices. Its design must be based on the needs of the employees and not separately planned and procured by corporate IT, facilities management or outlined based on the product offerings of technology vendors.

Embrace the Change. New tools, systems and work facilities inevitably change work practices. This change is often slower than expected and sometimes the promoted change never takes place. Careful planning, truthful marketing and well-timed information sharing enables successful change management. Communication of the proposed changes to the existing, even preferred, practices is most efficiently carried out by a well-known and trusted colleague that can act as a product champion.

Allow Well-Proven Work Practices. One should never deny the traditional and well-proven work practices, even when actively developing and adopting new ones. Especially tasks that rely on fine motor skills (sketching or drawing by hand) or include learning by doing (developing product ideas using post-it notes) are more natural and effective than using available digital solutions.

Invest in the Space. Where the collaboration space is situated affects its usage dramatically. If the space is readily available it will be used, but any additional steps, like cumbersome reservation systems, lessen the usage. The overall pleasantness of the space is increased by attractive décor, good ergonomics and well-functioning ventilation. These aspects become more important if the working sessions tend to last longer. The size of the space needs to comply with its intended use. All our observed cases suggest that bigger is better.

Preserve Adaptability. The collaboration space must be able to transform to meet the needs of different kinds of practices and group sizes. More flexibility is gained with adjustable furniture and by providing variety of both analog and digital tools to cater the preferred working habits of differing users.

Mind the Tools. A collaboration space and its supporting ICT systems should be seen as tools for a specific task. It is essential that the space does not obstruct the execution

of work tasks it is supposed to support. Interruptions in the usage, software bugs and encountered usability problems have a negative impact on work performance and satisfaction. They can irrevocably damage the users' trust towards the system and destroy their continuing motivation to use it.

Anticipate Integration to Other Systems. Any new collaboration system must integrate seamlessly to the organization's existing ICT infrastructure. The parties responsible for IT policies, privacy and data security should be engaged already in the planning phases to the development of a new collaboration space. Their role will become even more important during the adoption of the new system and they are eventually responsible for providing necessary training and support.

Consider the Feasibility. Simply adding a few large displays does not deliver answers on how to use them effectively and how to share information fluently. However, collaboration systems and facilities supporting multiple displays and multiple simultaneous users can easily become exceedingly complex. The currently available operating systems do not readily support multiple concurrent users, so it is necessary to make compromises. The complexity of the desired collaboration facility directly translates to a need for more tailoring and easily leads to higher equipment and development cost.

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