Towards Better Knowledge Work Experiences with New Ambient Workspace: Concept and Prototype

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Abstract—This paper presents a conceptual design of a dynamic and personalizable knowledge workspace suitable for collaboration in academic contexts. The concept of such workspace is aimed to cater the needs of students – as knowledge workers – for flexibility in various types of group and individual knowledge tasks. The research is focused on revealing challenges and obstacles faced by students who perform their daily knowledge work in current workspaces at various premises of Finnish campus. We propose solution that utilizes information technology and interior design. Based on literature on Ambient Intelligence and knowledge work, as well as our empirical user research, we designed a concept of flexible, transformable and user-friendly campus workspace with various features and functionalities. The concept is presented through visualizations and a semi-functional three-dimensional cardboard prototype. The workspace design itself is the main contribution of the current research. Dynamism, flexibility, personalization as well as features of the physical and mental engagement are principal novelties of proposed workspace for university students.

I. INTRODUCTION AND RELATED WORK

Knowledge work has became an integral category of modern life in post-industrial society. We can observe a growing demand for *symbolic* (mental practices with purpose, meaning and reference) and *interactive skills* rather than skills about manual labor [1]. The rising educational level and advances in science and technology increase the number of knowledge workers. There is a group of researchers emphasizing the symbolic nature of this type of work [2], [3] and underlining flexibility, innovativeness and individual creativity as key qualities of knowledge workers [4], [5].

Today, traditional office environments adopt desktop computers, laptops and various mobile devices as the major tools for knowledge work. Parayitam et al. admit that even though these devices were developed to serve users' needs, their constant usage may lead to a variety of issues such as stress and disunity of the colleagues in addition to lack of collaboration [6]. Another significant issue of knowledge workers is physical ailment, which is caused by the static and closed interactions. This results in sedentary lifestyle that ensues with mobility limitations leading to physical deconditioning [7], [8]. To decrease challenges in modern knowledge workers' practices, researchers and designers propose novel intelligent ambience designs that would combine multidisciplinary innovations from architecture, technology, psychology and medicine.

A. Ambient Intelligence in workspaces designs

Gill and Cormican introduce the concept of *ambient intelligence* (AmI) as omnipresent and proactive technology, which enables sensitive, adaptive and responsive digital environment [9]. Pervasiveness and sensitiveness are initial qualities of the intelligent environment that were already discussed at the beginning of 2000 by Krumm et al. [10] and later by Cook and Das [11]. Research outcomes show various AmI applications in healthcare, education, public services, leisure and entertainment, as well as in care of elderly and people with disabilities [12].

There are numerous projects on the development of Smart Home environments introduced in last decades. For instance, research and industry groups collaboration resulted in Gator Tech Smart Home [13], which is a prototype of programmable pervasive spaces for different application domains; Domus [14] and Aware Home [15] projects are mainly focused on spaces for elderly people. Augusto C. et al. address AmI application scenarios for multiple services including Smart Offices, Smart Decision Rooms and Smart Classrooms [16]. While Augusto et al. only introduce the application concepts of AmI workspaces, a research group from Stanford University has actually been developing an interactive dedicated space for task-oriented collaboration [17]. Such projects, in addition to intelligent artifacts designs [18], [19], [20], build new research opportunities for AmI knowledge workspaces.

Alcaniz and Rey state three major technologies for AmI environments as following: *ubiquitous computing* (embedded computers), *ubiquitous communication* (wireless networking) and *intelligent user interfaces* (natural way of control and interaction with AmI) [21]. While utilizing these technologies in knowledge workspaces design, it is also important to fulfill the workflow and well-being conditions. In this regard, research on workplaces by Nenonen S. is relevant as it describes the nature of workplaces for different phases of knowledge creation [22]. The author presents four main categories of spaces such as *connective* (for identity of the organization and its social structure), *structural* (for transformation of tacit knowledge to explicit, structural), *formal* (for explicit knowledge), *reflective* (for transformation of explicit knowledge to tacit) within two dimensions (*intangible and tangible work*). According to the author, the effective and productive workflow could be achieved in case of the combination of such dimensions. The non-disturbing and inconspicuous environment should facilitate workers' activities, thus, enhancing the job performance

Fig. 1. Examples of existing knowledge workspaces that have been observed and analyzed

and concentration. For well-being of workers, environment should be appealing and assist by empowering users' cognitive abilities, job satisfaction and motivation. It is also significant to reduce users' cognitive and physical load.

B. The concept of Pop Up workspaces

In regard to listed above requirements for AmI environments, a new concept of *Pop Up workspaces* was introduced in our previous research referring to temporary, modifiable and social workspace designs [23]. Accordingly, Pop Up workspaces utilize embedded computing that works in the background without operating effort from users [24]. It enables multimodal interactions with the environment in the most natural, smooth and relaxed way [25] giving the user freedom of movement. Previous research resulted in classification of five main experiences for Pop Up workspaces (*Liberty, Fellowship, Determination, Retreat and Recovery*) to conceptualize various innovative workspaces within the combination of ambient technologies, artifacts and space designs. Revealed outcomes and conceptualizations are utilized as design guidelines for proposed campus knowledge workspace in this paper.

In comparison with the past study case, we reveal students as the important category of knowledge workers. Students have multiple tasks facing a combination of aforementioned experiences. They are just at the learning or adoption phase of knowledge creation techniques. Daily learning activities are highly dependent on the provided workspaces and related equipment that may significantly affect the performance of users.

C. Research questions

We consider, campus knowledge workspaces as a supporting tool for collaboration among students is emerging research topic, which may bring new insights for general AmI and knowledge work studies. In this paper we address the following research questions:

1) What are university students' needs, expectations and requirements for collaborative Pop Up knowledge workspaces?

2) How to utilize existing AmI technologies to design dynamic and personalizable campus knowledge workspace that would support active (physical and mental) engagement and creativity in university collaborative work?

To address these research questions, we have conducted a human-centered design process that started by empirical user needs study and review of literature and resulted in a prototype of our design.

The rest of this paper is organized as follows. In Section 2, the methodology of the research and design process is described in detail, including findings from user data analysis and clarification of target users. Based on the user insight, Section 3 provides design goals, a vision of new campus knowledge workspace, detailed description of the features of the proposed design and presentation of a semi-functional three-dimensional (3D) cardboard prototype. In Section 4, key advantages, challenges and implementation risks are discussed in addition to future work. The last section concludes this work.

II. HUMAN-CENTERED DESIGN PROCESS

In this case study, human-centered design process was implemented within the Contextual Design framework [26]. Two Contextual Inquiries (CIs) were conducted in order to narrow down the target user groups and to become familiar with common people interactions and experiences in campus context. The methods of study include ad hoc interviews in target context and observation of group activity in context.

A. The first phase of the study – the process and outcomes

At the first phase, twenty random individuals from different university areas (see Fig. 1) were chosen and invited for a short interview for no more than five minutes in order to explore the scope of research tasks to design the ambient space. Questions in interviews were related to the difficulties of the work being done at the moment, preferences over any special locations and reasons for those, general physical and mental comfort the campus area, obstacles and challenges that are faced in general (e.g. noise, availability of the preferred space, furniture condition, privacy). This phase shifted the focus of the research and design to the collaborative group knowledge work. Additionally, different types of users were identified including researchers, faculty members, research projects representatives, and various students that are in need of space for any knowledge work. However, local/international, bachelor/master degree and exchange students were selected as target users for whom the concept of the campus knowledge workspace is designed. As it was already mentioned in the introduction, we consider students as the ones who belong to knowledge workers. Students spend more than eight hours daily in various university premises solving different intellectual tasks (i.e. study, exam preparation, individual and group

GROUPMATES ARE PERFORMING A JOINT TASK

WHO
There is a group of three international students at the university. Mohammad (18) is from Pakistan, Mario (25) is from Italy and Raffiq (20) is from Bangladesh.

BACKGROUND
Mohammad, Mario and Raffiq are from one course and working in the group doing assignment together. They study electrical engineering. The deadline for the group work is in three days. They are motivated to finish the task on a good mark and in time.

KNOWLEDGE WORK
Mohammad, Mario and Raffiq usually like places with enough lights and comfortable chairs. They prefer to modify environment according to their needs. For instance, they often move chairs closer to each other around the table. They don't like people speaking too loud around them, when they are working. Raffiq is very tall and has to move a lot to find comfortable position. Normally their meeting lasts two hours.

FRIENDS ARE SOLVING INDIVIDUAL TASKS

WHO
Three Finnish bachelor students: Ville (18), Mikko (20) and Aino (21).

BACKGROUND
Mikko, Ville and Aino are friends, and study different courses. In the evening they like study together by doing individual tasks.

KNOWLEDGE WORK
Mikko, Ville and Aino are meeting together for finishing own tasks. They like to study together as it motivates to continuous and long working process. However, independent learning alone is also suitable for them. Usually, assignments include reading material and/or writing reports or essay. During the meeting, Ville and Mikko use own laptop for doing tasks, while Aino uses such tools as pencils and notes, for her tasks she needs big table. It is common for them to be distracted by switching into other topics not related to their work.
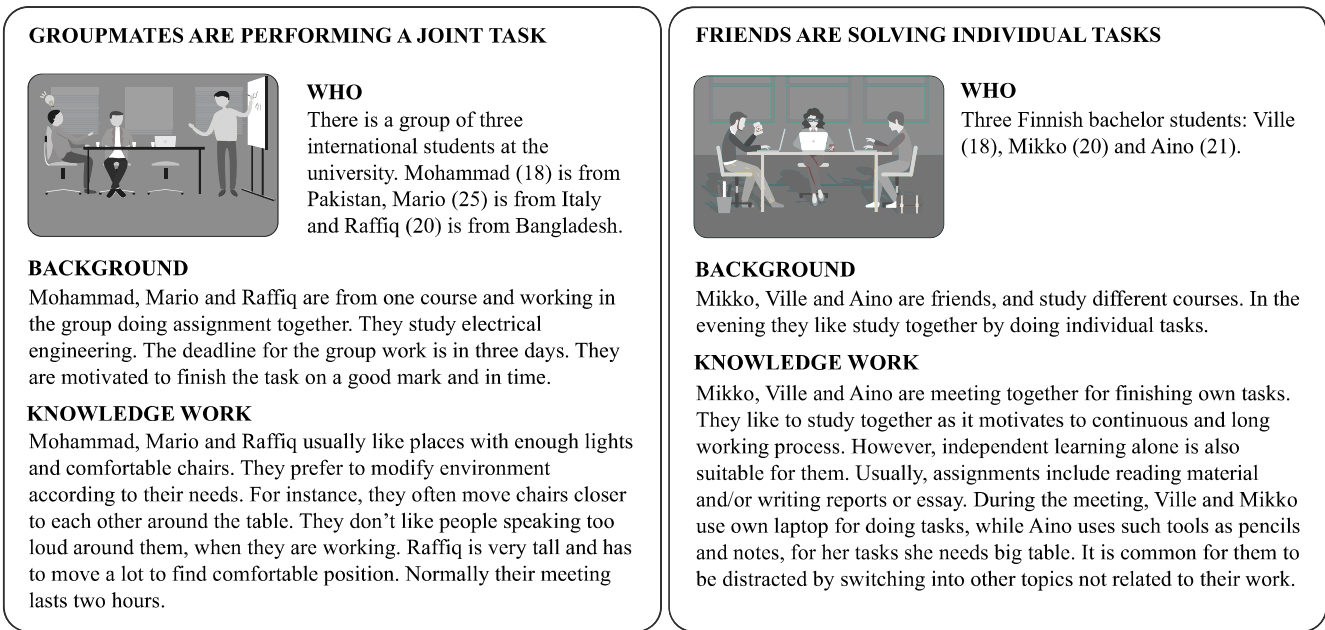
Fig. 2.   Group Personas for Pop Up knowledge workspace

work, brainstorming etc.). These academic activities require similar skills as from regular knowledge workers, such as *concentration*, *motivation*, *creativity*, *communication*, *critical thinking*, *team work* and many others. The primary student task was to perform intellectual work within the group of 2-4 people. Such work includes independent studies, accomplishment of practical assignments, brainstorming, preparation to exams and public presentations. Based on this knowldge, for design purposes we developed personas. Instead of adopting the traditional view of single user "*persona*", the "*group personas*" were developed. They primarily focus on the way people are conducting variety of collaborative knowledge tasks (see Fig. 2): **(i) Groupmates are performing a joint task.** There is possibility that most of the group members have not seen each other before. The duration of cooperation is usually less than two hours one or two times per week. The duration and frequency of the meetings may vary based on the task requirements and their severity. In addition to physical interaction, users are utilizing many devices such as laptops, smartphones, tablets, and project specific equipment. Depending on the task they may need extra tools to draw, display and observe (e.g. whiteboard or projector); **(ii) Friends are solving individual tasks.**This type of cooperation is based on personal preferences to work together, so all participants know each other and have good relationships. The main reason of working this way is mutual supporting in educational process as well as mental and social comfort in familiar company. The nature of such meeting is unofficial including casual knowledge work tasks.

B. The second phase of the study – the process and outcomes

During the second phase of CIs we observed and analyzed five groups of both international and Finnish students. Each group consisted not more than five people. Three out of five groups were implementing joint tasks for the courses. Most of the students in such groups were not familiar with each other before the initial meeting. Usually, they encounter only on purpose and do not spend additional time together. Other two groups are fellow students who spend time for fun and help each other to complete independent knowledge tasks. They usually use their own devices (laptops, smartphones) on such meetings and often get distracted from abstract talks.

The duration of observation was roughly one hour. The most significant moments of students' interactions were documented in photos and audio records (see Fig. 3). During and after the observation, participants of knowledge work were interviewed regarding specific actions, usage of artifacts, postures as well as about the environment and context in general.

Even though the study has provided us a variety of empirical knowledge, our focus is on the designing space. Thus, only the most central findings are reported here – those that were most useful to inform the design. We revealed four categories that require consideration in actual design process. The first category includes personal details such as suggestions to improve knowledge workspaces according to personal needs, requests in physical and mental comfort in addition to certain personal care requirements (e.g. special artifacts in use). The second category combines facts about the surrounding physical and social conditions. From the user perspective, the physical comfort could be achieved only in modifiable space.

In other words, people would like to have possibility to easily modify interior, lighting and artifacts if the place is not perfectly serves their needs. For the mental comfort, users have the desire to be safe and wish to belong to the community, while at the same time it is important for them to be isolated from the environmental disturbance. The third category contains users' complaints, advices and preferences related to various artifacts (e.g., desktop computers, charges, white-

boards, projectors, furniture and others). The last category refers particularly to the knowledge work process challenges and preferences on performing a group work (environmental qualities, schedule, furniture, equipment, etc.). In addition, the main challenges that users are facing were identified. First of all, isolated areas for group work are hardly accessible due to complicated online booking systems. Secondly, both isolated and open areas have non-flexible environment and the furniture is too heavy to move. In addition, there are significant issues with lighting and noise regulations. These results determined the major directions for design, based on which we built our hypothesis about future workspace features that are discussed in the following.

Fig. 3.   Students performing knowledge work at campus public spaces

III.   Pop Up Knowledge Workspace General Description

A. Design targets and concept vision

The most fundamental feature of the proposed system is to provide users a comfortable and suitable equipped space for intellectual work. Based on results from second phase we identified 5 major hypothesis on how to improve user knowledge work experience of students at campus: (i) There will be a need to book the Pop Up workspace, however current booking system has bad feedback from students, thus it requires redesigning; (ii) Current workspaces are lack of flexibility – it is hard to rearrange the space according to user's needs; (iii) Students experience mobility limitations while performing knowledge work at university work environments, which lead to lack of physical activation; (iv) There are often challenges related to resource management in a group work (e.g., displaying materials related to task only on one's laptop for everybody in a group); (v) The level of physical and mental comfort students experience at current workspaces should be improved.

To assess above-mentioned hypothesis we arranged meetings with 20 students who correspond to the target user group and asked them to rate their experiences on the scale from 1 to 10 (see Fig. 4). Participants of interviews were asked to rate:

- **Q1.** The level of comfort experienced while booking workspaces at the university.

- **Q2.** The flexibility of current workspaces.

- **Q3.** How physically active you are while performing knowledge tasks in current workspaces.

- **Q4.** The level of comfort of resource management experienced in current campus workspaces.

- **Q5.** The general level of comfort (both physical and mental) experienced in current workspaces.

As it may be observed from the plot presented in Fig. 4, the experience of using current workplaces at campus is quite poor – the given average rate is fluctuating from 1 to 5. This may be explained not only by the overall organization of such working environments but its accessibility and flexibility as well. Even though, it was clearly concluded that it is necessary to study and improve current joint working areas to bring the performance of knowledge work on the new level through applying AmI technologies and users data.
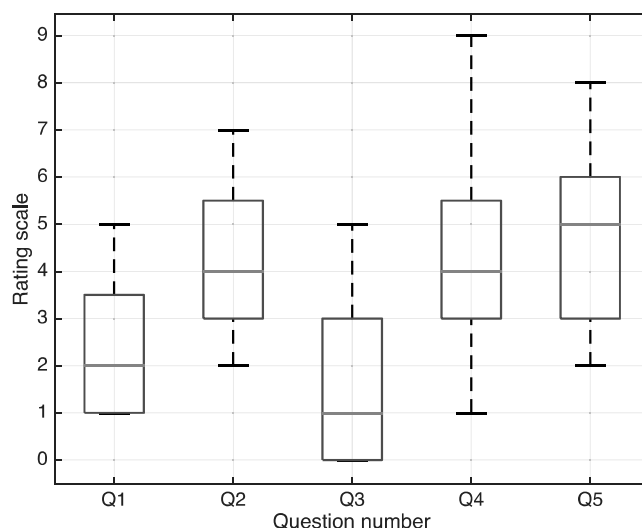

Fig. 4.   The rates of students experiences related to knowledge work at current workspaces at campus

Thus motivated by this results we developed the concept of innovative Pop Up area that could help to complete the tasks with high levels of efficiency and satisfaction. Accordingly, it is designed allowing users to: (i) Configure a physical space according to user needs and knowledge tasks; (ii) Gain access to user-friendly resource management; (iii) Contribute in a more natural way for both collective and individual knowledge work; (iv) Be physically active while performing knowledge work; (v) Experience both physical and mental comfort.

One of the basic factors taken into account for this project is healthcare. Evidently, sitting for a long period of time is not healthy [27]. Knowledge workers are more likely to spend a lot of time being in a static position than moving [28]. It may lead to bad posture and sore muscles causing serious health problems in the long run.

Another factor is the actual physical environment. Studies have shown that the environmental impact on how people
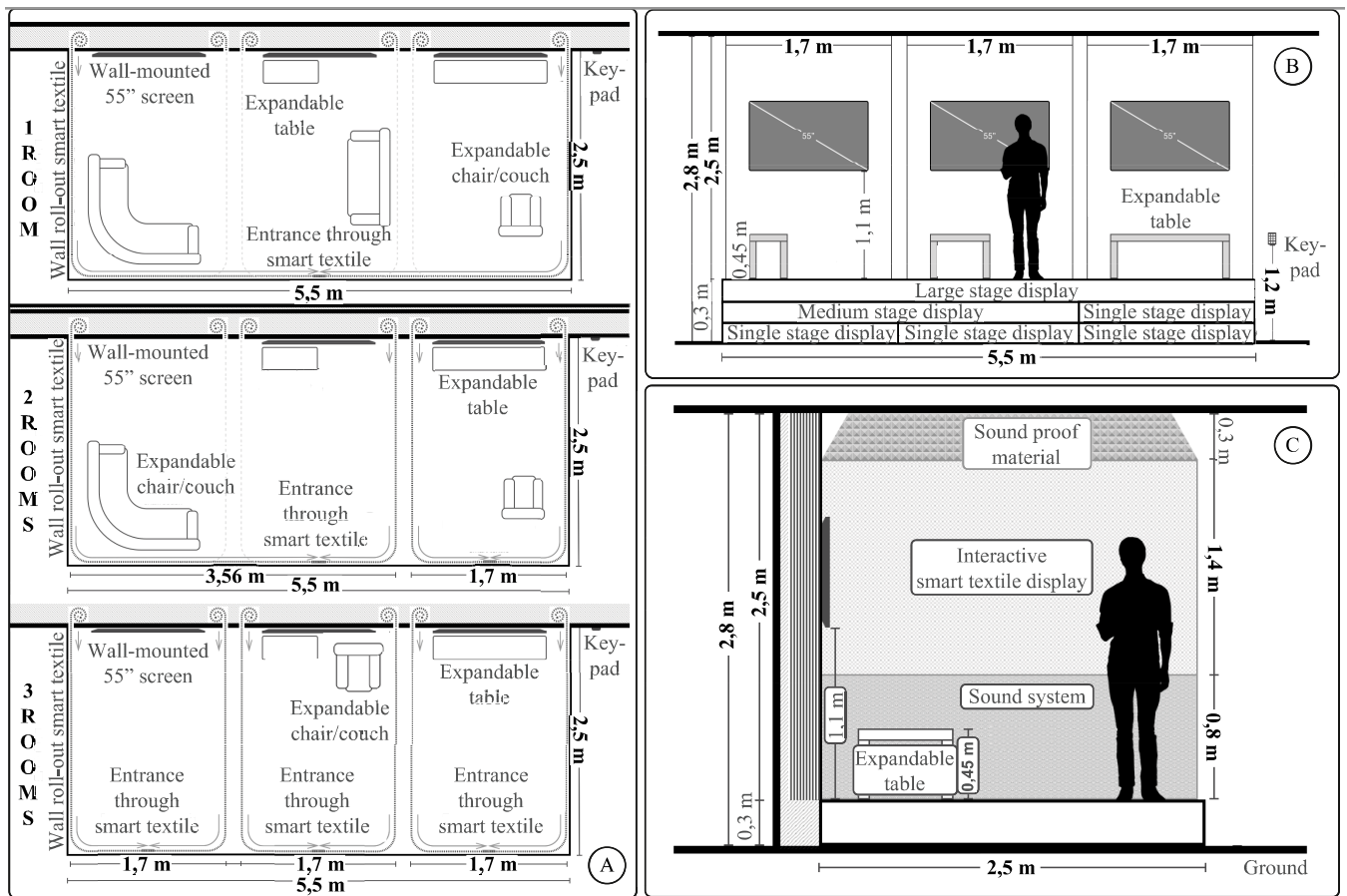
Fig. 5. Visualization of Pop Up knowledge workspace interaction elements from different views

are performing and how much it can affect them is extremely important [22], [29]. The proposed design concept of workspace aims to modify and improve traditional way of implementing the knowledge work. Additionally, designed environment enables rapid information sharing between group members and gives simple access to all academic resources provided by the university.

Pop Up knowledge workspace is designed as an interactive intelligent system to transform an open area into different rooms enabling knowledge work or relaxation environment for up to 9 people. The vision is to have a fully functional computer system that could be displayed on the fabric instead of traditional screen and can be operated by touch, voice and gestures like in a proper touch screen. The main purpose of the system is to assist users while they are performing their tasks and keep them physically active.

The design is based on a specific open stage area and combines the physical space with high-end technology of the smart textile. The main reasoning behind utilizing the smart textile is due to its flexibility that we aim to achieve.

The actual size of the open stage area is 5.5x2.5 meters and it is elevated from the floor by 0.3 meters. As specified by that measurement, the system can create three different sizes of rooms based on the number of participants: small room (1.7x2.5 meters) for 1 − 3 participants, medium room (3.5x2.5 meters) for 4 − 6 people and big room for group of 7 − 9 (5.5x2.5 meters) (see Fig. 5 A).

B. Functionalities

Campus knowledge workspace is designed to serve needs of students in three main phases as following:

1) Booking the space: As it was discussed earlier, users are facing significant issues with the existing way of booking spaces. It is difficult to find the booking system as it is integrated to the office 365 student's account. The university provides a five-page instruction on how to book learning spaces, which size we consider already demonstrates the complexity of the process. Therefore, the online booking system was developed allowing two modes of reservation − based on available rooms (see Fig. 6 A) and based on number of knowledge workers (see Fig. 6 C).

In the first mode users can choose the most suitable slot in calendar view and then input potential number of participants and duration of the session.(see Fig. 6 B)

Slots 1, 2 and 3 on the calendar view are metaphors of rooms that could be build. Accordingly, after user input the number of participants, the proper amount of rooms for comfortable knowledge work would be selected.

Fig. 6.   Booking System for Pop Up knowledge workspace

Another reservation mode requires firstly to input the number of participants and duration. In this mode, the date is optional field and in the end users receive all options in form of a list, which is ordered by relevance.

Once the confirmation of the reservation is complete, user obtains a secure code containing all the information required to build the actual space (see Fig. 6 D).

The design is made on the purpose of easy to use and let the user clearly understand the timetables and rooms availability. The color scheme follows the TUT design principles to be consistent with other TUT services. Additionally, the color palette in a timetable has certain meanings: green represents available selections, blue means user's selection and grey with texture refers to unavailable slots. Such way of color-coding was chosen according to familiar solutions in existing reservation systems (e.g. booking places in the airplane, train, etc.).

2) Building the space: A small arithmetic pad is mounted in the right wall of the open stage area. The user inserts the code, which is received from the online booking system and the physical space begins to transform. The design principle behind this transformation is the Japanese sliding doors. Two smart textile walls (one left and one right) roll out from the concrete wall at the same time. They slide on floor rails

and create a new closed room with open ceiling. Each room contains a 55" HD interactive touch screen mounted on the concrete wall and flexible cardboard furniture (see Fig. 5 B).

3) Interact with the space: The smart textile walls are divided into three horizontal zones as shown in the side view of the Fig. 5 C. The middle zone, which is the most significant one, can be used as a touch screen. The smart textile screen can be split in multiple parts, which gives the option to the group members to share resources and interact with them simultaneously. They have an ability to utilize all kinds of gestures (swipe, pinch, zoom, etc.) in order to interact exactly like with the actual wall-mounted touch screen. Users also have the option to connect to the system with their own personal devices via Wi-Fi or Bluetooth low energy (BLE) and gain access to the academic resources. Furthermore, the knowledge workers can change the amount of the interactive textile screens according to their needs.

The upper zone of the smart textile wall is fabricated from soundproof material, which has two purposes: to decrease the surrounding sounds as well as to prevent the noise that is generated inside the room to escape outside. While campus knowledge workspace is being configured, soundproof part of the wall gets tilted inwards by approximately thirty degrees and maintains an open ceiling. On the very top of this part,

a series of light-emitting diode (LED) spotlights provides the lighting. These lights can be dimmed according to the users needs. The bottom zone of the wall is used as the source of sound and music from playable media. Also, the area of textile walls connection next to the door/entrance is used as a whiteboard. Lights, sound, the number of textile screens and other features could be controlled from a permanent toolbar in the wall-mounted HD interactive touch screen.

One of the main ideas for the rooms is not to contain any traditional furniture like tables and chairs. The main reason for that is to make the users more active by standing, moving and walking most of the time while interacting with the touch screens. Instead, the campus knowledge workspace provides soft pillows, cardboard chairs and tables that can easily change size according to the number of people in each room. Initially, this furniture is hidden under the stage floor, which can be utilized as a storage room for personal items as well. All rooms will have names displayed in the front view of the elevated stage. In addition, this area (0.3x5.5 meters) can be used as a screen adding a joy element with multiple potential use cases, like displaying interesting and important information about university, upcoming events, advertisements, or even job references (see Fig. 5 B).

C. Prototyping

Two-dimensional (2D) visualizations of the proposed space design were used to build the semi-functional cardboard prototype (see Fig. 7). It includes pseudo-demonstration of features as part of the intelligent environment. The 3D model demonstrates the configuration of campus knowledge workspace made for accommodation of 1 – 3 people groups. The major accent is made towards interactive textile walls. There are different materials used to show particular areas of walls: transparent sheets for screen, coarse material for sound and thick draping for sound insulation. The positioning of lights has been shown in the walls as well. Also the model includes an example of flexible furniture (see Fig. 7) – folded and opened cardboard chair.

Fig. 7.   3D cardboard semi-functional prototype of the campus knowledge workspace

This prototype was used for the stakeholders' demonstration (students, university research groups, representatives of university space services, etc.) in order to receive a feedback and plan future implementation of the campus knowledge workspace.

IV. Discussion

To emphasize novelties and advantages of the proposed design, we compare it with previous research on Pop Up spaces. The most important distinction is that current research was shifted towards an implementation phase resulting in concrete target user group and development of the semi-functional prototype. Accordingly, Pop Up knowledge workspace could be considered as a logical continuation of the Ahtinen's study case [23].

Another difference relates to the research focus. While previous study case is mainly focused on identifying possible experiences, feelings and senses of *imagined users*, this paper provides an overview of real target user group (students), considering types of their collaborative tasks, interactions within a group and with environment. Additionally, in past research, concepts of workspaces were build on the basis of various probable *mindsets* (experiences) while we developed our prototype based on the actual users' data analysis, considering students complaints about existing workspaces, their needs, requirements and expectations for innovative space.

We can also conclude that for proposed campus knowledge workspace we combine design ideas from various mindsets revealed earlier – *Liberty* (collective work), *Fellowship* (collaboration work), *Determination* (conventional work in a group). For instance, the most important requirement for our design is to serve collaborative knowledge tasks. We utilized different qualities of Pop Up workspaces in our design without distinguishing such mindsets but. Thus, proposed campus knowledge workspace functionalities matched with the following selected workplace qualities proposed:

1) Activation: It is the most significant quality that enables physically active workflow with freedom of movements. In campus knowledge workspace, we implement this quality by making furniture optional. Additionally, interactive displays that could be controlled by natural commands (voice, gesture, touch) motivate users to stand, walk and collaborate with each other.

2) Variation: It is also one of significant qualities for knowledge workplaces that was taken into consideration in the proposed design. It refers to the idea of modification and changing the space according to user's needs. We designed and prototyped a flexible space with several modes discussed in the Section 3. We also suggested modifiable cardboard furniture to support the idea of flexibility.

3) Exploration: It is a quality that should support users in exploration of objects, situations or tasks. The main feature of the campus knowledge workspace is interactivity with intelligent displays (both wall-mounted and textile), because it simplifies the exploration tasks. The proposed workspace provides a user-friendly and synchronous document management – students have access to multiple academic sources and are free to explore/interact with related materials simultaneously on different displays.

4) Inspiration, Creativity and Sensation: These qualities refer to the idea that user should be inspired by the environment and have freedom of actions. These user senses should be stimulated with various materials and inspire through them. In our design, the focus is not given to the user feelings but to emphasizing enablers for the better knowledge work, i.e. we apply technologies and interior solutions that potentially may enhance inspiration and creativity of users. For instance, interactive displays and freedom of physical activities are aimed to promote or even encourage creativity of users and their willingness to innovate.

5) Connectedness, Being Part and Closeness: These qualities support the idea of working at the same place that is not totally isolated from the outer world. We fulfill this quality with movable walls that could be opened or closed depending on the space complexity level. Also stage displays are to visualize activities that happen in the room, involving people from outside to the knowledge creation.

Additionally, there are *Retreat* and *Recovery* mindsets that related to the individual level tasks. Usually such mindsets require isolation from other people, relaxation and recreation of both mental and physical powers. Even though our design was developed for collaborative knowledge work purposes, we do not exclude individual needs and desires. That is why different modes of rooms were suggested. A student who needs personal space could isolate himself from the outer world by using one small room. S/he can use pillows or flexible chairs to rest and turn on some relaxation videos. Therefore, by focusing on the wide range of the student needs and requirements, we have created a flexible, multi-purpose and adaptive space.

Within all advantages of campus knowledge workspace there are implementation risks and restrictions related to technology limitations. First of all, the smart textile does not exist to the extent we desire. Some of the current smart fabrics can light up or change colors while others can gather energy from the environment by harnessing vibrations, sounds or temperature and react to this kind of input [30], [31], [32]. Fully functional computer system that could be displayed on the fabric instead of traditional screen is the biggest constraint that we have come across so far and the biggest assumption as well. Another constrain concerning the smart textile walls is that they need to be really thin in order to be rolled. It may arise the problem of the material hardness, which should be stable and solid enough while users apply touch input.

Additionally, the sound/speaker on the bottom zone of the wall should also be thin. To solve this issue, we could utilize technology from the Kickstarter project by Richard Haberkern [33]. He created a thin film speaker that can be cut and shaped into any form. With the ability to reproduce a large range of audio frequencies, it could also be used to deliver audio in tight or unique spaces.

Nevertheless, utilizing such technologies will require significant costs. Hereby, we elaborate features that could be implemented right now. Continuing our idea of the flexible space, the Pop Up knowledge workspace could be at first implemented with cardboard walls that could be folded on principles of prototyped chairs. The surface of such walls could be used as a whiteboard (covered by specific material). In this way, users will interact with wall-mounted HD display and use

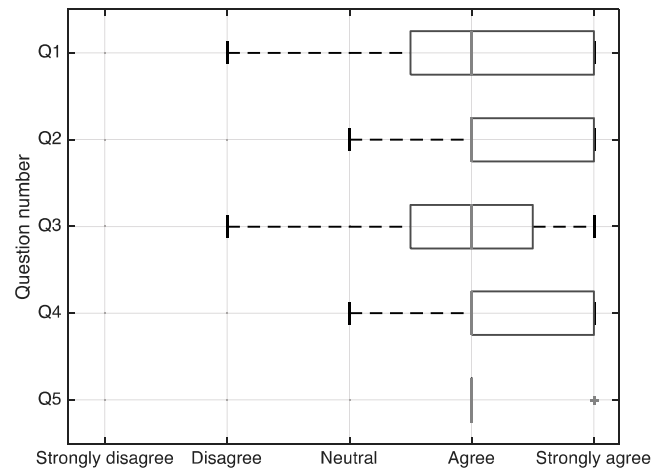large whiteboard space for notes, ideas and knowledge sharing.

Fig. 8.   The Pop Up knowledge workspace concept evaluation

A prototype of campus knowledge workspace was introduced to representatives of space allocation services in university and partial implementation of aforementioned design solutions is expected in the near future. To see any effects of the design would require to deploy a space with proposed features in a real context and for a rather long time, which is practically very challenging. Therefore, in this work we provide only the concept evaluation, which reveals subjective opinion of the same 20 students who earlier shared rates of their experience about current workspaces at campus. For the concept evaluation we utilized Likert scale [34] method to measure the participants attitude about proposed Pop Up workspace as a solution to support and enhance their performance of daily knowledge tasks. The results are demonstrated in the following graph (see Fig. 8) based on the following statements to agree or disagree on if the proposed design brings:

- **Q1.** Ease of the workspaces booking.

- **Q2.** New feature of flexible workspaces allowing building spaces according to needs and/or tasks.

- **Q3.** New physical engagement.

- **Q4.** More comfortable way of resource management.

- **Q5.** More natural way of interaction with the workspace supporting both collective and individual knowledge work.

As it is observed from Fig. 8, the overall user expectations regarding the proposed workspace design are positive. The main benefit to be delivered for the participants is more natural way of the interaction, which currently does not fulfill the usability requirement. The most questionable task seems to be a higher level of physical involvement provided. It is mainly due to the lack of users understanding of a need to have such an activity during the working process as they are used to the passive way of performing knowledge tasks in their daily life. For further research we would like to study how physical engagement incorporated with ambient learning spaces may

improve students performance at knowledge work and bring innovativeness to tasks' processes.

V. CONCLUSION

To summarize, in this work we firstly gained empirical findings of people's needs for knowledge workspaces in public campus areas. Secondly, we propose a design concept of a new campus knowledge workspace as the main contribution of current research. Such workspace is aimed to support efficient collaboration, active engagement (physically and mentally) and use of different skills in a group work. We combined and reconsidered findings from previous AmI and knowledge work research enabling the following features for our design: modifiable space that could be transformed into several rooms; user-friendly access to academic resources; convenient synchronous document management; more natural interaction models for both collective and individual knowledge work; freedom of physical activities; improved connectedness among group members and belonging to the community. The resulted design embodies novel aspects in terms of *dynamism* and *active engagement*, and we hope it serves as an inspiration in campus design in the future.

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