



THE PROCESS OF PARTICIPATORY ERGONOMICS SIMULATION IN HOSPITAL WORK SYSTEM DESIGN

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Keywords: participatory design, human factors and ergonomics, hospital work systems, simulation-based design

1. Introduction

When designing new hospitals, engineers and architects take design decisions that will influence the work taking place in the new hospital. The building design influences organization of functions, communication between workers and patients, application of medical technologies and conduction of work practices. All these parts together constitute the hospital work system. A work system “comprises two or more people working together, interacting with technology within an organizational system that is characterized by an internal environment (both physical and cultural)” [Kleiner 2006]. Thereby, design of new hospital buildings also includes design of new hospital work systems.

Participatory ergonomics simulation (PES) is a method to design new hospital work systems. It is based on involvement of workers in simulation and design of their own future work system [Daniellou 2007]. PES is applied within the field of Human Factors and Ergonomics and draws on principles from the field of Participatory Design. The purpose of PES is to design ergonomics work systems by applying a participatory design approach. Ergonomics work systems means that the work system support of both human well-being (e.g. physical, cognitive etc.) and overall performance (e.g. quality, efficiency etc.) [International Ergonomics Association 2015].

PES consists of four elements. The first element is a simulation medium, which visualizes and represents the future work system to be designed, e.g. an architectural blueprint of a future building. The second element is scenarios of the future work that will take place in the new work system. The scenarios are defined beforehand. The third element is participation of workers, who are the future users of the new work system. The fourth element is facilitation of the PES.

These four elements are combined during PES events either as narrative simulation or experimental simulation. Narrative simulation is based on participants discussing scenarios on how to conduct the future work in the new work system [Daniellou 2007]. Experimental simulation is based on participants acting out how the future work could be conducted in the new work system [Daniellou 2007]. In both narrative and experimental simulation, facilitation of the process is crucial in order to guide the process and ensure an ergonomics work system design. Despite of this, a thorough understanding of the process of PES has gained low attention. However, to understand the PES process is important when planning and facilitating PES, with the intension of reaching ergonomics work system design.

1.1 Existing research and aim of study

Existing research on participatory design processes have highlighted four different perspectives of the participatory design approach. An overview is presented in Table 1 and related to the elements of PES.

Table 1. Four different perspectives on participatory design

Perspectives	Keywords for the perspectives	Relation to PES elements
Visualization by media	Prototypes, models, games etc. have the role as mediators between participants [von Hippel 1994, 2009], [Béguin 2003], [Dindler 2010], [Broberg et al. 2011], [Bratteteig and Wagner 2012], [Lucero et al. 2012], [Steen et al. 2013], [Andersen and Broberg 2015]	First element; simulation media, which visualize the future work system and are applied in the PES.
Experimenting and reflecting	Exploration and experimentation of possible design solutions from a human-centred design perspective [Valkenburg and Dorst 1998], [Brown 2008, 2009], [Binder and Brandt 2008], [Broberg and Edwards 2012], [Taffe 2015] Review and evaluation of possible solutions [Valkenburg and Dorst 1998], [Détienne et al. 2012], [Andersen and Broberg 2015], [Taffe 2015]	Second element; scenarios that are applied in experiments of the future work in PES.
Different participants' contributions and perspectives	Sharing of experiences, perspectives and information by participants from different domains [von Hippel 1994, 2009], [Garrigou et al. 1995], [Béguin 2003], [Broberg and Hermund 2007], [McDonnell 2009], [Bratteteig and Wagner 2012], [Scariot et al. 2012], [Xie et al. 2015] Conflict, tension and negotiation as process drivers [Béguin 2003], [Taveira 2008], [Buur and Larsen 2010], [Détienne et al. 2012], [Patel et al. 2012], [Bowen et al. 2013], [Dolonen and Ludvigsen 2013], [Xie et al. 2015]	Third element; participating workers with different backgrounds contribute with different experiences in PES. They also have different interests that possibly can foster conflicts etc.
Collaborative space	Metaphorical and temporary collaborative spaces fostering innovation [Binder and Brandt 2008], [Brodersen et al. 2008], [Dindler 2010], [Bratteteig and Wagner 2012], [Lucero et al. 2012]	Fourth element; facilitation, which involves establishment of a temporary and metaphorical space for the PES to take place.

The assumption of this study is that the different perspectives are interrelated and together constitute the process of PES. Therefore, this study investigates the interrelations of the perspectives with the aim of developing a framework describing the process of PES in hospital work system design. The intension of the framework is to assist practitioners in planning and facilitation of PES in hospital work systems design. The framework is developed based on a case study of two cases of PES in hospital work systems design. Analysis of observations and interviews resulted in identification of five interconnected elements that together constitute the PES framework. In the following, the case study and framework are presented and discussed together with the implications for ergonomics interventions and practitioners.

2. Methodology

The case study methodology [Thomas 2011] applied focusing on two cases of PES in hospital work system design. The cases were selected on a maximum variation criterion [Thomas 2011] in relation to variation in the design phase where PES was applied. The first case applied PES in the form of table-top simulation in the early design phase of a new outpatient department. The second case applied PES in the form of blueprint simulation in the last design phase of a new intensive care unit (ICU). The maximum variation strategy was applied because of the argument that identification of commonalities in maximum varying cases strengthens the findings [Thomas 2011].

2.1 The case of table-top simulation

This case was part of designing a new outpatient department at a major Danish hospital. As a part of the early and conceptual design phase, healthcare workers from the existing outpatient department were invited to participate in four PES events as presented in Table 2. The aim was to develop a conceptual design proposal for the layout of the new outpatient building and the work system going to take place in the building. The PES events were a public private collaboration between the outpatient department,

ergonomics researchers, simulation consultants and consultants from industry. The PES events were facilitated by one of the simulation consultants. The simulation medium applied in the PES events was a table-top model. This model constituted of cardboard boxes, LEGO figures, marker pens and an A0 poster as shown in Figure 1. The cardboard boxes were placed on the poster and represented the future examination rooms in the outpatient department. Placing the cardboard boxes in different ways, different building layouts could be visualized. The LEGO figures depicted healthcare workers and patients. The simulation participants were each assigned a role and a LEGO figure corresponding to their professional background, e.g. the physician was assigned the physician LEGO figure. The researchers and the consultants from industry were assigned patient LEGO figures.

Table 2. The four PES events constituting the case of table-top simulation

	PES event 1	PES event 2	PES event 3	PES event 4
Focus	Separate examination and conversation rooms	One examination room per two conversation rooms	Multifunctional examination rooms and staff area	Development of multifunctional examination rooms
Participants	One physician, one nurse, one medical secretary, one consultant from industry, two simulation consultants, three researchers.			Three nurses, three physicians, two consultants from industry, one simulation consultant, three researchers.

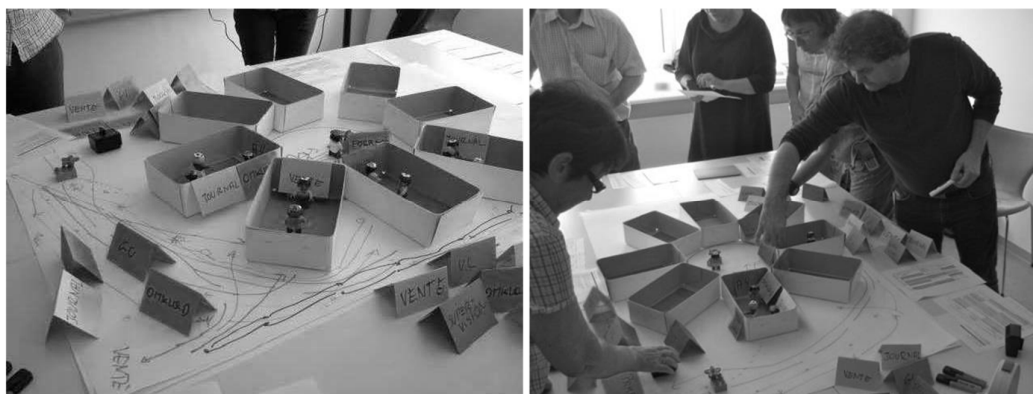


Figure 1. Left: The table-top model, right: A table-top simulation

The facilitating simulation consultant and the outpatient management had beforehand defined scenarios based on different types of patient examinations. The scenarios consisted of a list of actions in relation to the examinations. Each action had a simulation time assigned as a third of real time. The simulation participants acted out the scenarios by applying egg-timers for timing the different actions of the scenarios. During the scenario acting, the participants moved the LEGO figures around the table-top model and drew the movement on the A0 poster using the marker pens.

After each scenario acting, the simulation consultant facilitated a discussion among the participants in relation to obtained ergonomics insights. The discussion led to proposals of design changes, which were implemented by changing the configuration of the cardboard boxes and explored through new scenarios acting.

2.2 The case of blueprint simulation

The second case was part of designing a new intensive care unit (ICU) at a smaller Danish hospital. The physical department was designed during a previous design process involving both designers and workers from the existing ICU. However, in the last design phase, right before the workers moved into the new department, the work system of communication methods, technology application and work practices, still needed a detailed design. As part of the work system design, healthcare workers from the existing ICU were invited to participate in PES. This study focuses on four of the PES events, as

presented in Table 3. The events were arranged by the executive nurse and the nurse in charge of work practice development. Furthermore, the PES was facilitated by two organizational consultants from the regional human resource department. The simulation medium applied in the four PES events was blueprints combined with LEGO bricks and LEGO figures as illustrated in Figure 2. The blueprint was A0 size and illustrated the design of the new ICU. The LEGO figures depicted healthcare workers and patients and the LEGO bricks illustrated hospital beds.

Table 3. The four PES events constituting the case of blueprint simulation

	PES event 1	PES event 2	PES event 3	PES event 4
Focus	Testing and developing the future work system taking place in the new ICU			
Participants	Two nurses, Three coordinating nurses, One physiotherapist, One executive nurse, One work practice development nurse, Two organisational consultants.	Three nurses, One coordinating nurses, One service assistant, One medical secretary, One executive nurse, One work practice development nurse, Two organisational consultants.	Four nurses, Six coordinating nurses, One occupational therapist, One executive nurse, One work practice development nurse, Two organisational consultants.	Three nurses, Three coordinating nurses, One occupational therapist, One service assistant, One medical secretary, One executive nurse, One work practice development nurse, Two organisational consultants.



Figure 2. Left: The blueprints and LEGO figures, right: A blueprint simulation

The nurse in charge of developing work practices had beforehand created five scenarios. The scenarios were everyday situations, which likely would happen in the new ICU work system. The simulation started by one of the participants reading aloud a scenario. This led to the participants placing LEGO figures on the blueprint to depict the healthcare workers and patients as described in the scenario. The scenarios included a series of questions on how to handle the everyday situation in the new work system. These questions were the foundation of exploring different ways of designing and organizing the work practices. The exploration was first based on the participants moving the LEGO figures on the blueprint in accordance with the scenarios. This led to discussions of possible solutions on the scenarios, which led to new scenarios acting with the LEGO figures. After each scenario, the facilitators asked the participants to reflect and write down suggestions for the future work system.

2.3 Data collection and analysis

Data collection was based on observations of the PES events and interviews with selected simulation participants. The observations were based on an observation guide focusing on the PES process of each event. The interviews were semi-structured [Kvale 1996] and based on an interview guide focusing on the participants' experiences of the PES events. The interview respondents are listed in Table 4. The observation notes and interview transcriptions were analysed through coding. The initial coding protocol was based on the four perspectives of participatory design identified in the existing research in section

1.1. The coding protocol was revised concurrently with the analysis through an iterative process of analysing data and evaluating the protocol [Miles and Huberman 1994]. The analysis resulted in identification of five elements across the two cases. These five elements and their interrelations were proposed as a framework describing the PES process in hospital work system design.

Table 4. Interview respondents

Table-top simulation	Blueprint simulation
One nurse, one medical secretary, two consultants from industry, two simulation consultants, two researchers, one physician.	Two coordinating nurses, one service assistant, one organizational consultant, one executive nurse, one work practice development nurse.

3. Results

The identified five elements and their interrelations are proposed as a framework describing the process of PES in hospital work system design. The framework is presented in Figure 3 and elaborated in the following sections.

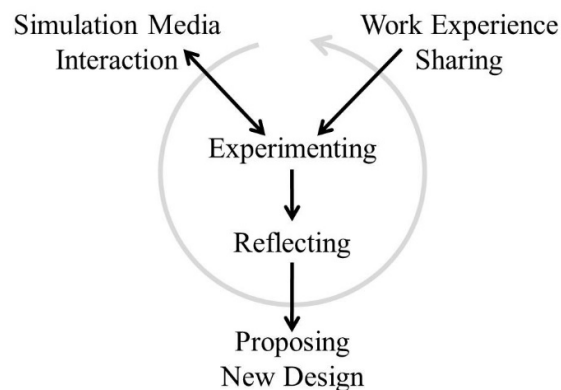


Figure 3. The proposed PES framework

3.1 Experimenting with the future

The observations showed that a central part of the PES was participants exploring and experimenting with different designs of the future hospital work system. Therefore, experimenting was identified as the central elements in the framework.

Experimentation was as well a topic receiving attention in the interviews. Participants described PES as a process of testing: ‘We tried out different designs... the advantage was that we tested and orchestrated several different working procedures and then selected the one we liked the best.’ - Medical secretary, table-top simulation. Experimentation also included a discussion part: ‘The important thing was that it [the blueprint simulation] encouraged the “what-if” discussions’- Executive nurse, blueprint simulation. Thereby, experimentation supported both testing and discussion of future work system design.

3.2 Interacting with the simulation media

From the observations of the PES events, the two types of experiments showed to be tightly related to the simulation media: the table-top models and the blueprints. The simulation media visualized the future work system design: ‘The blueprint and the LEGOs made it concrete and visual, and then you reach it [a new design proposal] together.’ - Coordinating nurse, blueprint simulation. The visualization ability of the simulation media was observed to foster the testing and the “what-if” discussions. By configuring the cardboard boxes in different ways, the participants of the table-top simulation tested several different work system design possibilities related to the building layout and organisation. By distributing LEGO figures and LEGO bricks in different ways at the ICU blueprint, the participants of

the blueprint simulation could discuss different ways of designing the future work system of the work practices. Several of the respondents described that the application of simulation media distinguished from the situation of “only sitting and talking”. It [the table-top model] was concrete ... and realistic.’ – Nurse, table-top simulation. ‘This [the blueprints] was practical, and you could start playing with it.’ – Executive nurse, blueprint simulation. ‘...The LEGO figures turned alive, and you became the role you were playing’ – Consultant from industry, table-top simulation. Thereby the simulation media added an element of “serious play” to the PES.

Whether the experiments led to interaction with the simulation media or revers was not clear from the analysis. Therefore, the identified connection between these two elements was illustrated as a two-way arrow in the proposed framework.

3.3 Sharing of work experiences

The observations revealed that during the experimentation, the different participants contributed with knowledge and experiences from their own work and professional background. The respondents emphasized the importance of having participants with different backgrounds. The experience sharing was described as: ‘We obtained different perspectives on the same matter, so you got a sense of the other participants. The nurses think as their profession and secretaries think as their professions.’ - Physician, table-top simulation. ‘I heard one [a service assistant] say that service assistants also had a role at the morning meetings. [Somebody asked] “But why do they actually have that?” [The assistant answered] “Because we are also a part of the planning”, “ah, okay I see...”’ - Executive nurse, blueprint simulation. A common topic in the interviews was that the contribution and sharing of work experiences resulted in understanding of other professions’ challenges and needs in the future work system. ‘I heard that people said; “Okay, that’s how you see it. That was not how I saw it”’- Work practice development nurse, blueprint simulation. Thereby, the sharing of experiences contributed to the testing and discussion in the experiments and the relation between these two elements was thereby illustrated in the proposed framework by a one-way arrow.

3.4 Reflecting on the experiments

The experimentation was observed to lead to the participants reflecting on the new insights obtained from the experiments. The insights were often realizations about the ergonomics consequences of the work system design explored during the experiments. The realizations were described as: ‘There were occasionally some whoops’. Like “oops, but that’s not possible, because so and so”. For example, the waiting time could not be avoided, if there was a young doctor, who had to wait for an experienced doctor.’ - Medical secretary, table-top simulation. Such whoops-realizations also led to new experiments.

Furthermore, reflections also supported participants realizing that their personal assumptions on the future hospital work system design were perhaps not relevant. An example of this is described as: ‘Apparently, there had been “myths” about the distances in the new building would be very far. But when they [the healthcare workers] stood by the blueprint, they saw that this was actually not a problem. So the story [the myths] could suddenly be stripped away’ - Organisational consultant, blueprint simulation. In this way, the PES also showed a change management purpose by being an initiative in decreasing resistance to change in relation to the implementation of new hospital work systems. The relation between the experiments and reflections was illustrated as a one-way arrow in the framework.

3.5 Proposing new design

The PES events included the participants and the facilitators documenting proposals for new design criteria and new designs of the future hospital work system. The criteria and design proposals developed from the participants’ reflections was a reaction for improving the ergonomics challenges realized. In the table-top simulations the participants proposed a new outpatient department layout and new work procedures to minimize walking distances and improve utilization of time. In the blueprint simulation the participants proposed a new work organization and new work practices to minimize the psychosocial workload on the nurses and improve coordination. These criteria and design proposals were the outcomes of the PES.

The formulation of design criteria and development of new designs were observed to be a joint activity among the participants. Also described by a respondent: 'It was funny that we all realized the same solution. Namely, that we had to move the coordinating function. We were all agreeing on that, and we had not talked about it [that solution] before.' – Coordinating nurse, blueprint simulation. The joint activity also resulted in trade-offs in relation to the different participants' interests. '... We each had our own "I-want-that"-approach... that did not make it easier, because then we had to move around with the elements each of us wanted.' - Nurse, table-top simulation.

The relation between the reflections and development of new design proposals was illustrated as a one-way arrow in the framework.

3.6 An iterative process

The five elements identified and interrelated were observed not to be as linear as indicated in the previous sections. Instead, the process was highly iterative, and the participants went through the elements several times. This iteration is illustrated as a circular arrow in the background of the proposed framework.

4. Discussion

This study investigated the interrelations of the elements in PES with the aim of developing a framework describing the process of PES in hospital work system design. The elements of the framework are discussed in the following sections.

4.1 Resources for experimenting

The analysis showed that PES in the two cases was based on experiments. However, the experiments showed to be highly supported by the visualization capabilities of the simulation media and the shared experiences of the participants. Thereby, the simulation media and sharing of work experiences can be seen as resources for the experiments.

The resource ability has been recognized in existing participatory design studies. Interaction with visualizing artefacts in the form of prototypes and games has been described as experimental [Binder and Brandt 2008], [Broberg et al. 2011], [Taffe 2015]. Furthermore, sharing of workers' experiences has been identified in experimental activities [Béguin 2003], [Broberg et al. 2011]. However, these experiment resources have not been related to reflections on ergonomics consequences. Thereby, experiments are not the final goal of participatory processes such as PES, but are a mean to foster the outcome of PES in the form of new ergonomics work system design.

4.2 Reflections by non-professional designers

Existing studies on participatory design, such as PES, have identified the benefits of reflection in participatory processes. Reflections are conceptualized as reflexive practice, as continual reviewing and as evaluation of design moves [Valkenburg and Dorst 1998], [Détienne et al. 2012], [Taffe 2015] and is described as the central move towards a design solution. But the existing studies have mainly concentrated on collaborative design between professional designers. This study shows that reflections also are essential in participatory design groups of non-professional designers. This opens for the possibility that other parts of reflexive design practice of professional designers might also be relevant in participatory design processes with non-professionals.

4.3 Proposing new design as a joint activity

The reflections showed to lead to participants proposing new work system design. The proposal was developed as a joint activity including negotiation and trade-offs, which can be related to the existing studies on group dynamics and negotiation in participatory design [Béguin 2003], [Taveira 2008], [Buur and Larsen 2010], [Détienne et al. 2012], [Patel et al. 2012], [Bowen et al. 2013], [Dolonen and Ludvigsen 2013], [Xie et al. 2015]. The proposal of new design in PES is thereby influenced by group dynamics. However, the existing studies have mainly concentrated on the group dynamics and not how this is encouraged through experiments and reflections as identified in this study.

4.4 The application of the PES framework

The framework developed from the two case studies is intended to be a tool in planning and facilitation of PES in ergonomics interventions in hospital work system design and other related sectors. The PES method is relevant in both corrective, preventive and prospective ergonomics interventions [Robert and Brangier 2009]. Incremental changes through correction of identified problems in existing work systems can be tested through PES. Prevention of ergonomics problems in new design can be introduced through PES as presented in the two case studies. New prospective innovations in future work systems can be developed through PES initiatives.

The three ergonomics approaches influence the elements: simulation media and experience sharing. In corrective ergonomics, a simulation medium visualizing the incremental changes to a high degree of detail is important for conducting realistic simulations. Furthermore, participation of workers with experiences in the existing problems is relevant for PES in corrective ergonomics. The preventive ergonomics can benefit from a flexible and malleable simulation medium in order to support experimentation with many different solutions. Here participation of the future workers is relevant. Prospective ergonomics innovations would include more than workers as participants, but also marketing, professional designers and researchers.

These examples show that the PES framework can support practitioners reflecting on the elements of the PES process when planning PES in different types of ergonomics interventions. Furthermore, understanding of the different elements' interconnections in the PES framework is relevant for practitioners that are facilitating PES. The PES framework shows that the facilitator should encourage the participants to reflect on experiments, because reflections are related to development of new design proposals. This can ensure the progression of the PES process towards the intended outcome.

4.5 Limitations and further research

This study is a case study of two PES cases, both contributing to design of new hospital work systems. The results are thereby drawn from an in-depth understanding of the PES processes of these two cases. This limits the generalizability of the results [Thomas 2011]. However, the results can be an opportunity for learning from cases and applying principles of this learning in other related contexts [Thomas 2011]. The limited generalizability opens up for further research into participatory design processes such as PES. Further research could benefit from including more empirical data. This data could be additional case studies or other types of data for the purpose of triangulation [Thomas 2011]. Furthermore, testing of the PES framework in planning and facilitation of PES in other sectors can result in further development and detailing towards a more solid framework and increase the knowledge about the application.

5. Conclusion

The aim of this study was to develop a framework describing the process of PES in hospital work system design. The framework was developed from analysis of two cases of PES: table-top simulation of an outpatient department and blueprint simulation of an ICU. With outset in four different perspective of participatory design, observations and interviews from the two cases were analysed. During the analysis the four perspectives developed into five elements together constituting a framework describing the process of PES across the two cases. The five activities were as follows. The simulation media in the form of table-top models and blueprints were together with the participants' experiences from the existing work the resources of the simulations. Through interaction with the simulation media and sharing of professional experiences the participants engaged in experiments of the future work system. The experiments were in relation to both acting of the future work and discussion on how to carry out the future work. Both types of experiments showed to lead to participants reflecting. The reflections were related to how the design of the future work system would influence the future work and ergonomics conditions. The reflections resulted in the participants proposing a new work system design through negotiations of new design proposals or formulation of new design criteria. The identified elements and their relations were illustrated and proposed as a framework describing the process of PES in hospital work system design.

The framework can potentially be applied in other work system design contexts e.g. work system design in production companies. The intention is that the framework can assist in planning and facilitation of PES processes. Understanding of the elements and their interrelations strengthens the facilitation of efficient and goal oriented PES processes.

5.1 Implications for practitioners

Three proposals of implications for practitioners' planning and facilitating PES in work system design:

- Participants with different professional backgrounds are essential for obtaining different experiences and intentions contributing to the experiments. However, be aware that the process of reaching jointly decided design proposals has to be facilitated through negotiations.
- Consider to apply simulation media that support experiments of different work system design. Thereby, the simulation media should visualize the parts of the work system of interest in the simulation and be flexible in use.
- Including small breaks in the experimentation can potentially leave time for reflections on the ergonomics consequences of the work system design. The reflections potentially lead to participants proposing new design and formulating design criteria.

Acknowledgement

A gratefully acknowledgement to the financial support of the Danish Working Environment Research Foundation, grant number 36-2012-09.

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