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The role of knowledge objects in participatory ergonomics simulation

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Participatory ergonomics simulations, taking place in simulation labs, have the tendency to get detached from the surrounding design process, resulting in a knowledge gap. Few studies in the human factors and ergonomics field have applied knowledge management based object concepts in the study of knowledge generation and transfer over such gaps. This paper introduces the concept of *knowledge object* to identify the roles of objects in an exploratory case study of five participatory simulation activities. The simulations had the purpose of contributing to room design of a new Danish hospital. The analysis showed sequences and transitions of the knowledge objects revealing the process behind the knowledge interpretations and development of the future hospital rooms.

Practitioner Summary: When planning participatory simulation in a lab context, the ergonomist should consider the role of objects in generation of ergonomics knowledge and transfer of this knowledge to actors in the surrounding design process. Design actors receiving simulation documenting objects interpret and transform the represented knowledge according to their local context and experiences.

Keywords: Participatory Ergonomics, Simulation, Knowledge Objects, Architectural Design

1. Introduction

This paper presents an exploratory case study of participatory ergonomics simulation (Daniellou, 2007) applying full-scale mock-ups in design of a new Danish hospital. The simulations took place in a ‘simulation lab’ providing resources for building and exploring full-scale mock-ups. Within participatory design research, such labs have been defined as design labs (Binder and Brandt, 2008), interactive laboratories (Watkins, Myers, and Villasante, 2008), imaginative places (Brodersen, Dindler, and Iversen, 2008) etc. The lab provides the possibility for experimenting within a stable and controlled environment (Binder and Brandt, 2008; Watkins et al., 2008). This characteristic has the tendency to detach the participatory activities taking place within the lab from the surrounding and less controllable design process. This can be an advantage as defined by Brodersen et al. (2008) as elements of transcendence that “fuel the process of creating distance from current practice…” and “…open up the horizon of opportunity”. However, the detachment of the lab might as well result in a gap between the lab and the surrounding design process. The gap needs to be overcome when sharing the knowledge generated within the lab.

Within the knowledge management field, objects in different kinds have been introduced in overcoming gaps or boundaries in knowledge sharing (e.g. Carlile, 2002; Ewenstein and Whyte, 2009; Gherardi and Nicolini, 2000). However, within the field of human factors and ergonomics, research of the knowledge sharing properties of object have been few. The characteristics of objects in direct interaction and communication between production workers and engineers are highlighted by Broberg et al. (2011). Objects, such as scale models and layout games, showed to support sharing of ergonomics knowledge during participatory ergonomics activities in a manufacturing redesign process. The characteristics of objects in communicating information over time and place are emphasized in the study of Conceição et al. (2012). Guidelines were designed to transfer ergonomics knowledge from offshore accommodation units to onshore design teams. Hall-Andersen and Broberg (2013) combine both the communication and transfer characteristics in analysing an engineering design process of a hospital sterile processing plant. Objects such as blueprint drawings and guidelines showed to assist knowledge sharing between ergonomists and engineers. This paper determines the objects of these three studies as *knowledge object*.

Knowledge objects are objects that support generation and/or transfer of ergonomics knowledge. They act as representations of ergonomics knowledge and their purpose is to overcome gaps between different design actors. This paper introduces the knowledge objects concept within an exploratory case study to investigate the role of objects applied in participatory simulation activities. This implies both the generation of ergonomics knowledge and transfer of this knowledge over the gap between the detached simulation lab and the surrounding design process.

1.1 Theoretical approach on knowledge objects

The knowledge object approach originates from the field of science and technology studies (STS). The STS argue for objects playing just as significant a role as human actors in sociotechnical processes, and often the role as mediators between different actors (Latour, 2005; Vinck, Jeantet, and Laureillard, 1996). The concepts of intermediary object (Callon, 1991; Vinck et al., 1996) and boundary objects (Carlile, 2002; Star and Griesemer, 1989) have been applied in the few studies of knowledge objects within human factors and ergonomics. Intermediary objects are "…objects that can be communicated and exchanged between design partners" (Vinck et al., 1996). Hall-Andersen & Broberg elaborate by highlighting that "an intermediary object is an object produced by a network of designers with the specific intent of transferring their knowledge and experience to downstream actors". In this paper designers are viewed as any actor involved in design activities. Boundary objects create a sheared understanding between actors from different social worlds (Star and Griesemer, 1989) and "…facilitates a process where individuals can jointly transform their knowledge" (Carlile, 2002). Hall-Andersen and Broberg (2013) add a term of boundary objects being "mediators in the direct communication between actors".

Drawing on the work of Nicolini et al. (2012) the concepts of intermediary objects and boundary objects can be seen as secondary objects of collaboration, thereby secondary knowledge objects. These concepts provide a significant value in the understanding of how knowledge is generated and transferred across different boundaries. However, they do not focus on the primary knowledge object, thereby why knowledge is generated and transferred. By introducing the concept of epistemic objects (Ewenstein and Whyte, 2007, 2009; Nicolini et al., 2012; Rheinberg, 1997) the 'why' and the motivation of the knowledge generation and transfer can be unfolded.

Epistemic objects "fuel cooperation and general mutuality and solidarity by triggering desire and attachment and creating mutual dependencies" (Nicolini et al., 2012). They are defined by their incompleteness (Cetina, 1996) and evolve when knew knowledge is discovered (Ewenstein and Whyte, 2007). An epistemic object is partially expressed in multiple instantiations, such as the secondary knowledge objects in the form of the intermediary objects and the boundary objects. Because of the fluidity of epistemic objects, they can be manipulated and evolved through these secondary knowledge objects (Ewenstein and Whyte, 2009; Whyte, Ewenstein, Hales, and Tidd, 2007). In contrast to the epistemic objects, Rheinberg (1997) defines the concept of technical objects. These are ready-to-hand, complete and unproblematic instruments (Ewenstein and Whyte, 2009), which are frozen in nature (Whyte et al., 2007). Epistemic objects are turned into technical objects when exploring and concretizing the unknown (Ewenstein and Whyte, 2009). The relations between the four knowledge objects concepts are presented in table 1.

Table 1. The relations between the four STS concepts of knowledge objects.

		Primary knowledge objects	
		Epistemic objects	Technical objects
Secondary knowledge objects	Intermediary objects	EI-objects: Represents a fraction of the not yet fully defined object under design. It transfers the represented knowledge to down steam actors. It is fluid in nature. Thereby, the receiving actors can interpret and manipulate the representation.	TI-objects: Represents a fully defined and unquestionable part of the object under design. It transfers the represented knowledge to down steam actors. It has a frozen nature. Thereby, it is stable to the receiving actors and not manipulated in any way.
	Boundary objects	EB-objects: Represents a fraction of the not yet fully defined object under design. It mediates direct communication between different actors. It is fluid in nature. Thereby, the actors can communicate and generate knowledge by manipulating and transforming the representation.	TB-objects: Represents a fully defined and unquestionable part of the object under design. It mediates direct communication between different actors. It has a frozen nature. Thereby, the participating actors do not manipulate it during the communication.

2. Method

This paper is based on an exploratory case study of participatory ergonomics simulation taking place within a regional simulation lab in Denmark. The lab was established for contributing to the design process of a new major hospital, a merger between two existing regional hospitals. The primary resources of the lab were full-scale mock-ups facilities. By applying movable chipboard walls, foam bricks and standard hospital furniture, the facilitators of the lab constructed design proposals for future hospital rooms. These mock-ups were staging the simulation events, with the purpose of testing and developing standard rooms to be repeated throughout the new hospital building design. The participants of the simulations were healthcare professionals from the existing hospitals, project employees and consultants. The participants adjusted the mock-ups during the simulations, leading to a redesign of the tested hospital room design. The case study investigated five simulation events in depth, presented in table 2.

Table 2. Overview of the five simulation events.

	Sim 1	Sim 2	Sim 3	Sim 4	Sim 5
Area of design	New beds ward reception area.	New beds ward corridor including a bed paternoster lift.	New outpatient examination room.	New depot for bed ward.	New cancer day treatment ward.
Partici-pants	4 secretaries, 2 charge nurses, 1 hospital management, 2 IT consultants, 2 facilitators, 1 project employee.	1 hospital porter, 1 technical employee, 2 project employees, 2 technical consultants, 2 facilitators.	4 secretaries, 2 charge nurses, 1 hospital management, 2 IT consultants, 2 facilitators, 1 project employee.	2 nurses, 2 project employee, 1 facilitator.	2 charge nurse, 1 nurse, 2 facilitators.
Simu-lation process	Participants were standing in the mock-up discussing future work scenarios, leading to adjustments of the mock-up.	Participants acted out different scenarios by manoeuvring a standard bed through the mock-up, leading to mock-up adjustments.	Participants were standing in the mock-up discussing future work scenarios, leading to adjustments of the mock-up.	Participants were acting out scenarios of work practices and at the same time furnishing the rooms according to the practices.	Participants were standing in the mock-up and acting out scenarios of work practices, leading to adjustments of the mock-up.

Data collection was based on observations of the five simulation events, which as well were video-recorded. After each simulation event a selection of participants were interviewed about their experience of the simulation. The selection of interviewees was based on the criteria of gaining a variety of different professions. Each interview was documented in a summary including transcriptions of the parts related to the aim of the study. Furthermore, the documents applied or created in relation to the simulation activities were collected. The different types of data was analysed with the theoretical approach of knowledge objects. The analysis had two foci; 1) identifying objects having a role in the knowledge generation during the simulation activities and in the knowledge transfer to the surrounding design process, and 2) investigating the roles of these objects from the perspective of the four STS concepts of knowledge objects.

3. Findings and discussion

The following sections present the identified knowledge objects of the five simulations. Furthermore, the roles of the identified knowledge objects are analysed and discussed by applying the STS knowledge objects concepts.

3.1 Architectural blueprints transfer knowledge to the lab

Before the simulation events the facilitators received a blueprint drawing of the initial design from the consulting architects, see figure 1 left for an example. The blueprints represented the design proposals to be tested and redesigned during the five simulation activities. The facilitators built the design proposals as mock-ups, which then represented the blueprints in 3D and full-scale. The facilitators strived to build the mock-ups as close to the blueprints as possible. However, they needed to adjust according to the mock-up materials available, e.g. the reception desk in simulation 1 was represented by a foam block instead of a real desk. Other parts of the blueprints were left out of the mock-ups because the facilitators considered them to be irrelevant, e.g. neighbouring rooms.

The blueprints can be seen as representations or ‘codifications’ (Gherardi and Nicolini, 2000) of the architects’ knowledge at that stage of the design process. This knowledge was transferred to the facilitators in the simulation lab, who translated the blueprint into mock-ups, limited by the material possibility. They interpreted the codified knowledge and translated it according to their local context and experience (Gherardi and Nicolini, 2000). Thereby, the blueprints had the characteristics of intermediary objects. At the time of transferral, the blueprints had a stable nature, representing well-defined designs of the future hospital rooms. However, the blueprints were sent to the simulation lab for exploration and testing. Thereby, the appropriateness or suitability of the designs was in question. This unfroze the blueprints, which became the trigger of the construction of the mock-ups. This change of status can be seen as the blueprints changing roles from technical object into representations the future desired rooms as epistemic objects. The transition is illustrated in figure 1 right.

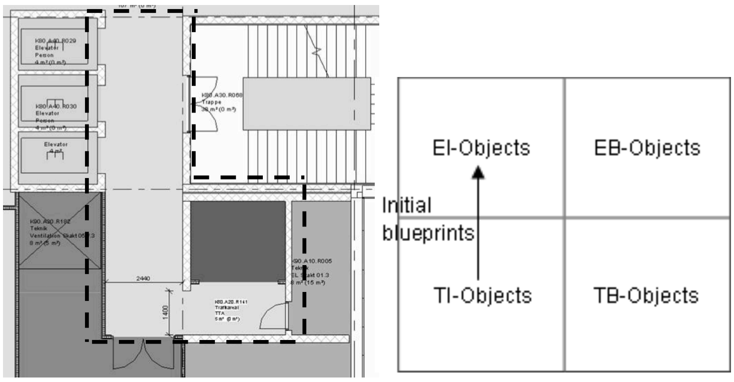

Figure 1: Left, blueprint of the bed ward corridor. The dashed lines show the part that was builded as full-scale mock-ups. Right, transition of the initial blueprints provided by the architects.

3.2 Full-scale mock-ups generate knowledge within the lab

In all the simulations the mock-ups, as representations of the future hospital rooms, were the primary desire and driver of the events. The participants explored the architectural design proposal by bodily experiencing the mock-ups. During discussion and acts of future user scenarios, the participants obtained an understanding of how the initial design would influence the work practices intended to take place in the room. This led to participants suggesting adjustments of the mock-ups and thereby adjusting the room design. The adjustments were easily implemented because of the flexibility of mock-ups in relation to the movable chipboard walls, foam bricks and standards hospital furniture. The adjustments resulted in an experimental approach, which is illustrated in the observed sequence of adjusting and reflecting from the second simulation event in figure 2 left.

The experimental approach made the participants reflect during the simulation events. The reflections led to generation of a common understanding of the ergonomics challenges, and how to cope with these through continually adjustments. This process continued until an acceptable design was agreed upon by the participants with different experience and background. Thereby, the mock-ups had the characteristics of boundary objects, by being mediators in the direct interaction between the different participants seen as belonging to different social worlds (Carlile, 2002; Star and Griesemer, 1989). The experimental approach was supported by the fluid nature of the mock-ups. The movable chipboard walls, foam bricks and standard hospital furniture made it easy for the participants to constantly transform the mock-ups according to the evolving common understanding. The participants were throughout the simulation trying to concretize and define the incomplete hospital room and the work practices taking place within this room. In that way, the mock-ups had the characteristics of being representing the desired future rooms as epistemic objects. Throughout the adjustments the lack of completeness decreases and the mock-ups started to be more frozen in nature in terms of being concretized. In so, the mock-ups turned towards technical objects. The transition is shown in figure 2 right.

Hospital porter:	(Pulls the extra-long hospital bed out of the paternoster lift by pulling the headboard. Starts turning the bed at the same time with the purpose of being prepared for driving down the corridor, when the bed is out of the paternoster. The space is limited and it seems like the bed is incapable of getting out.)
Project employee:	"Uhhhh"
Consultant:	"Take it easy, bear in mind it's the extra-long bed we are trying now." (She addresses the project employee.)
Hospital porter:	(Goes to the foot of the bed, which is half way out of the paternoster now, and pulls out sideways the foot end. Suddenly the bed's wheel collides with the foam brick representing a slide door of the paternoster lift. The foam brick is moved out of place and the foam wall is almost collapsing.)
Architect:	"A door just crashed" (Walks towards the foam brick)
Facilitator:	"But the difference was that because we made the corridor narrower?" (Points at the movable wall opposite the paternoster lift.)
Architect:	"Yes, I think so". (Putting the foam brick into place again.)

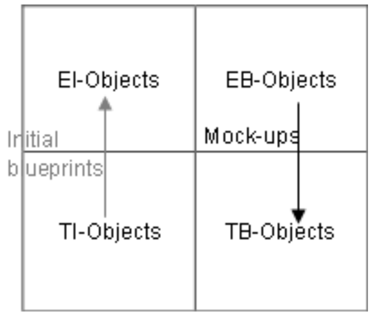

Figure 2: Left, experimentation of turning the hospital bed in different width of the corridor. Right, transition of the mock-ups during the simulation events.

3.3 Documents, lists and notes sustain and transfer generated knowledge out of the lab

In all simulations, objects were produced during or directly after the events, with the purpose of documenting the generated ergonomics knowledge and design adjustments. Table 3 presents an overview of the produced object. These objects had the ability of sustaining the results and the generated knowledge of the simulation events. The sustained knowledge was highly influenced by the actors producing the objects. The facilitators and the project employee, producing the objects in simulation 1, 3, 4 and 5, had a high focus on the clinical and ergonomics conditions. This was reflected in the documents and sketches by including e.g. ergonomics considerations of the space around work stations. The participating architect producing the objects in simulation 2 had a high focus on the room dimensions. This was reflected in the notes by including e.g. minimum dimensions of the corridor for the bed to turn.

The produced objects were afterwards transferred from the simulation lab to the surrounding hospital design process. The purpose was to transfer the generated ergonomics knowledge to actors in the design process for integration in the hospital design. In simulation 1 the receiving architect interpreted the document and list, and then adjusted the original blueprint according to that interpretation. He interpreted a point of attention on discretion of patient information as mainly focused on the back-office reception area. Thereby, he integrated a glass wall and door for separating the reception desk and the back-office without blocking daylight. However, the discussion among the simulation participants had also concerned discretion in the reception desk area. The generated knowledge was thereby distorted in the transfer. In simulation 3, 4 and 5 the same kind of distortion was identified. In these simulations the introductions of new furniture and dimensions were not interpreted by the receiving architects in the same way as discussed by the simulation participants.

In simulation 2 the interpretation went more straightforward, because the architect in charge of integrating the simulation outcome participated in the simulation activity. He produced his own notes and transferred these directly to the surrounding design process. In this case however, the adjustments of the original blueprint implied moving a wall into a neighbouring ventilation room. This task started a negotiation process with the engineers in charge of the ventilation system. The original blueprint was the basis for the engineers verifying that the architect could move the wall according to the design adjustments created during the simulation. The transformed blueprint of simulation 2 is presented in figure 3 left.

Table 3. Overview of the produced objects for sustaining generated knowledge

	Sim 1		Sim 2	Sim 3	Sim 4	Sim 5
Objects produced	Descriptive document.	Adjusted furniture list	Design notes on post-it	2D sketch.	2D sketch.	Descriptive document
Producing actors	Facilitators	Project employee	Participating architect	Facilitators	Facilitator	Facilitators
Focus	Adjusted dimensions, ergonomics consideration and patient information discretion	Adjusted number of work stations and inclusion of new technology	Adjusted dimensions of the corridor	Adjusted arrangement of the interior to increase patient experience	Adjusted dimensions and interior to optimize work practices	Adjusted arrangement of the interior for ergonomic work stations
Time of production	Right after simulation	Right after simulation.	During simulation	Right after simulation	During simulation	Right after simulation
Way of transfer-ring	Through common database	Through space management software	Physically transferred to architectural office by the participating architect.	Through common database	Through common database	Through common database
Receiving actors	Architect in charge of bedward reception area. Not participating in simulation	Architect in charge of bedward reception. Not participating in simulation	Architect in charge of the bedward corridors and paternoster lifts. Participated in the simulation	Architect in charge of outpatient department. Not participating in simulation	Architect in charge of bedward depot. Not participating in simulation	Architect in charge of day treatment ward. Not participating in simulation

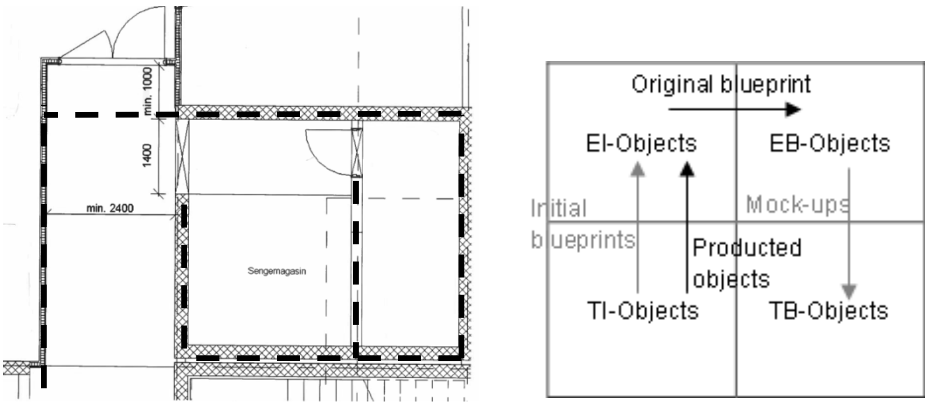

Figure 3: Left, adjusted blueprint of the corridor and paternoster lift. The dashed lines show the dimensions of the initial blueprint. Right, transition of the produced objects and the original blueprints.

The produced objects showed the abilities of freezing the generated knowledge by codifying the producers' view on the simulation outcomes (Gherardi and Nicolini, 2000). This codified knowledge was transferred to architects in the design process, who acted as downstream actors (Hall-Andersen and Broberg, 2013). Thereby, the produced objects had the intermediary objects characteristics of transferring knowledge. The knowledge transferred was stable design changes decided upon, relating to the characteristics of technical objects. However in simulation 1, 3, 4, and 5, interpretation of the transferred knowledge showed to have a significant impact on the transformation of the original blueprints. The architects interpreted and translated the objects according to the architects' own degree of freedom in the local but complex design context:

"If I get information, which doesn't fit the building shape and format, I need to analyse it… I analyse what I think their (the facilitators of the simulation) intensions are and then try to press it into the squire I have available. I analyse it with my experience as foundation and the knowledge of the department I have after all." – Architects in charge of bed ward, including reception and depot

The translation opened up the frozen nature of the transferred intermediary objects, because the architects considered the codified knowledge to lack the constraining conditions of their local context. This lack turned the stable transferred objects into a representation of fluid epistemic objects. The transition is illustrated in figure 3 right.

In simulation 2 the transferred intermediary object, in the form of the design notes, was held relative stable and remained to be a technical object. Instead the original blueprint played a more significant role. The original blueprint was unfrozen in the action of the architect sending it to the simulation lab for testing and development. In this action the blueprint transferred knowledge from the architect to the simulation facilitators as an intermediary object. In the discussion between the architect and the ventilation engineers taking place after the simulation, the original blueprint remained fluid as an epistemic object. But it was also supporting the communication between the architect and engineers at the spot of the negotiation of moving the corridor wall. The negotiation resulted in the architect and engineer reaching a common acceptable solution, relating the blueprint to the characteristics of boundary objects. Thereby, the blueprint was in both situations a representation of the future design as the epistemic object, but changed the secondary knowledge object role from being an intermediary object to being a boundary object. The transition is shown in figure 3 right.

4. Concluding remarks

The exploratory case study of five participatory ergonomics simulations showed that knowledge objects support knowledge generation and transfer in participatory ergonomics simulation taking place within a simulation lab context. The STS based knowledge objects approach enabled identifying and analysing objects' roles in the ergonomics knowledge generation and transfer. The knowledge objects identified were the blueprints of the initial room design, the mock-ups and the produced objects sustaining the outcome of the simulations. All these knowledge objects were in different ways representing the objects of desire; the future hospital rooms. When the rooms were under development in the simulation lab and in the surrounding design process, the room design could be considered to have a lack of completeness. This lack of completeness showed to be the driver of the knowledge generation and transfer, leading to the knowledge objects having characteristics of epistemic objects. During all the simulations, the room designs were occasionally frozen, leading to a stable representation of the desired rooms and thereby having the characteristics of being technical objects.

The representing objects were per se not the direct reason for the knowledge generation and transfer, thereby not the primary knowledge objects. However, their roles as secondary knowledge objects in the form of intermediary objects and boundary objects cannot be neglected. They highlight how the epistemic objects of future hospital rooms develop. Transformation of the intermediary objects and boundary objects resulted in transitions between fluid design suggestions and relative frozen suggestions and vis-à-vis.

The identified knowledge objects occurred in sequences revealing the process behind the development of the future hospital rooms. The sequences included actors generating, interpreting and translating the objects according to their different experiences and local contexts. Thereby, the generated and transferred knowledge was constantly adjusted. Especially the interpretations of the objects produced during or after the simulations resulted in knowledge distortion when transferred over the gap between the simulation lab and the surrounding design process.

Suggestion of implications for practitioners:

- When planning participatory ergonomics simulation in simulation lab contexts, ergonomists should consider the primary knowledge object, which should motivate the process of ergonomics knowledge generation and transfer.
- Furthermore, secondary knowledge objects representing and transforming the primary knowledge object should be considered in relation to their ability of assisting knowledge generation and transfer.
- Secondary knowledge objects transferred between different actors are interpreted and translated according to the receivers' context and experience. Thereby, the number of different actors involved in the production and interpretation of the objects should be at a minimum for decreasing knowledge distortion. Thereby, direct involvement of the designers in the simulation activities is preferable.

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