

# *Virtual collaborative design environment: supporting seamless integration of multitouch table and immersive VR*

Article

Supplemental Material

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**Table 1.** Preliminary coding schema for observations based on CVE-literature.

Primary codes	Analytical focus of observations and video based data
1. Shared Context	To understand and evaluate if the collaborative design activities and the system: <ul style="list-style-type: none"><li>- enables shared understanding and interactive activity for the group and its different participants.</li><li>- enables understanding, creativity, collaboration, participation and communication between the different stakeholders.</li></ul>
2. Awareness of others Knowledge sharing	To understand and evaluate if: <ul style="list-style-type: none"><li>- the system and collaborative design activities support tacit knowledge sharing related to the design problem</li><li>- the team build up shared understanding of the design problem and that different stakeholders begin to better understand each other's perspectives.</li></ul>
3. Transitions between shared and individual activities	<ul style="list-style-type: none"><li>- To consider if individual work evolves into collaborative work and does the multi-touch table and VR-system complement each other during this collaborative design activities.</li></ul>
4. Negotiation and communication	<ul style="list-style-type: none"><li>- To consider and understand how negotiation and communication was done during collaborative design activities.</li><li>- To understand and evaluate if multi-touch table support negotiation and communication e.g. action space and VR-system complement with understanding of space and reflection during collaborative design activities.</li></ul>
5. Flexible and multiple viewpoints – different design spaces	<ul style="list-style-type: none"><li>- To understand if design tasks require the use of multiple representations and visualizations during collaborative design activities.</li><li>- To understand and evaluate if multi-touch table and VR-system support multiple representations and visualizations of the design problem e.g. multi-touch table support collaboration and action space and VR-system support reflection, individual work and better understanding of space</li></ul>

Note: CVE-literature (Snowdon et al. (1998; 2001), Arias et al. 2000; Fisher et al. 2005)

**Table 2.** Summary of observation from first part of workshop 2, connected to CVE-literature categories.

Observation Cases from Video Data	1	2	3	4	5
<b>Summary of Observation Case 1: Designing small room</b> However, during the workshop the <i>participants recognized</i> that when all the equipment and furniture were added it was not possible to move equipment around during the surgery- see Fig. 4, right side, small room.	✓	✓			
<i>The anesthesiologists theatre nurses stressed that a surgery is a lot about logistics</i> , where equipment moves around during surgery, pointing that some equipment is very big sized and hard to move such as X-ray equipment (C-arch).					
This assumption was <i>tested using the HMD</i> , which enabled the <i>participants' shared understanding that the standard sized room was to small from logistics reasons regarding the equipment</i> .	1. Shared Context ✓	2. Awareness of others Knowledge ✓	3. Transitions between shared and individual activities ✓	4. Negotiation and communication ✓	5. Flexible and multiple viewpoints – different design spaces ✓
<b>Summary of Observation Case 2: Designing Large Room</b> When the <b>architect realized that the room was small</b> , she proposed shifting the focus of the workshop on designing the larger room. The result of the layout design for equipment and furniture in the large room can be seen in Fig. 4, left side large room.	1. Shared Context ✓	2. Awareness of others Knowledge ✓	3. Transitions between shared and individual activities ✓	4. Negotiation and communication ✓	5. Flexible and multiple viewpoints – different design spaces ✓
During the workshop, <i>the participants recognized that the equipment and furniture must be centered around the patient and the operating table</i> , which led to noting that some space in the large room remained unused. Consequently, the <i>participants used the multi-touch table to add a wall for simulating a shrunken version of the room. As the wall was added, one of the nurses was simultaneously in the HMD to validate the room size</i> . As shown in Fig. 4, the participants shrank the room one more time after <i>feedback from the nurse in the HMD</i> .	✓	✓	✓	✓	✓

Note: 1 = Shared Context; 2 = Awareness of others Knowledge sharing; 3 = Transitions between shared and individual activities; 4 = Negotiation and communication; 5 = Flexible and multiple viewpoints – different design spaces; CVE-literature (Snowdon et al. (1998; 2001), Arias et al. 2000; Fisher et al. 2005).

**Table 3.** Summary of validation of the ViCoDe-system and Co-design activities connected the CVE requirements, observation connected to technology and collaborative design activities.

CVE requirements	Observations		ViCoDe design activities	Result from Observation:
	Multi-touch	VR		
<p>✓ = Fully (✓) = Secondarily</p> <p><b>1. Shared Context</b></p> <ul style="list-style-type: none"> <li>- enables shared understanding and interactive activity for the group and its different participants.</li> <li>- enables understanding, creativity, collaboration, participation and communication between the different stakeholders.</li> </ul>	(✓)	✓	✓	<p><b>Multi-Touch:</b> gave difficulty in fully understanding the 2D. However, <b>VR</b> gave better understanding of the space and -how theater would actually function and work</p>
<p><b>2. Awareness of others and knowledge sharing</b></p> <ul style="list-style-type: none"> <li>- the system and collaborative design activities support tacit knowledge sharing related to the design problem</li> <li>- the team build up shared understanding of the design problem and that it emerges as different stakeholders begin to better understand each other's perspectives.</li> </ul>	✓	(✓)**	✓	<p><b>Multi-Touch:</b> enabled the users to be actively engaged in the development of the design in a dynamic and interactive way and the mobilized knowledge sharing. <b>VR</b> **see below.</p>
<p><b>3. Transitions between shared and individual activities</b></p> <ul style="list-style-type: none"> <li>- individual work evolves into collaborative work and the multi-touch and VR complement each other during this collaborative design activities.</li> </ul>	✓	✓	✓	<p>** Individual activities in <b>VR</b> gave input to multi-touch of how the operating theater would actually function and work.</p>
<p><b>4. Negotiation and communication</b></p> <ul style="list-style-type: none"> <li>- To consider and understand how negotiation and communication was done during collaborative design activities.</li> <li>- To understand and evaluate if multi-touch support negotiation and communication e.g. action space</li> <li>- To understand and evaluate if VR complement with understanding of space and reflection during collaborative design activities.</li> </ul>	✓	(✓)**	✓	<p><b>Multi-touch</b> supported negotiation and face-to-face communication and gestures. <b>VR</b> **see above.</p>
<p><b>5. Flexible and multiple viewpoints</b></p> <ul style="list-style-type: none"> <li>- To understand if design tasks require the use of multiple representations and visualizations during collaborative design activities.</li> <li>- To understand and evaluate if multi-touch and VR support multiple representations and visualizations of the design problem e.g. multi-touch support collaboration and action space and VR support reflection, individual work and better understanding of space</li> </ul>	(✓)	(✓)	✓	<p><b>Multi-touch:</b> Limited understanding and perception of the space and of design problem, but where the interactive collaborative design was carried out <b>VR</b> presented the design in 1:1 scale however has limitation when it the overview of the design. By seamless integration of a multi-touch table and VR that supported interactive and collaborative design work in different design spaces</p>