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A CO-CREATION TOOL IN WALK-IN VIRTUAL ENVIRONMENT: MAKING PROSPECTIVE WORK VISIBLE

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A CO-CREATION TOOL IN WALK-IN VIRTUAL ENVIRONMENT: MAKING PROSPECTIVE WORK VISIBLE

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Abstract

The focus of this paper is on user participation in product design process. Ours is a human-centred approach in which users' expertise is acknowledged and which addresses the development of future products, rather than the current situation in users' work. This type of user participation applied to co-creation is possible when the users' prospective work is made visible. This paper presents a tool with which product users' can experiment working with the product under design. As the product designers can observe the users' actions with the tool, their understanding of the users' work practice increases and their discussions with the users improve. The tool, VIP2M, is a virtual environment for prototyping a mobile working machine and constructing it in a walk-in virtual environment. We built it following the tradition of design science research and evaluated it by user tests. The study shows that virtual environment is a useful base for constructing appropriate tools for product users' participation in the product design.

Keywords: Co-Creation, User, Walk-In Virtual Environment, Product Development, Work Practices, Virtual Prototyping, Design Science.

1 Introduction

User participation in product design process is a practical reality. Present Internet technology and online communities can be utilized for virtual co-creation of new products (Di Gangi and Wasko, 2009). However, the scientific roots of user participation in the design process are variable and include their connections to information systems (IS) and work development (Ehn, 1988, Greenbaum and Kyng, 1991), creation of new methods for aiding user participation in the design process (e.g., Kensing et al., 1998, Lenne et al., 2009) and tools for supporting communication between users and designers (e.g., Bødker, 2000, Luck, 2007).

One of the main challenges in user participation is the negotiation between the designer and the user of the product. The negotiation is problematic since the participants' underlying assumptions are different (e.g., Davidson et al., 2001, Luck, 2007). In practice this means that the interaction is not easy, because designers and users do not have a common terminology. Designers often use technical terminology and dominate users (Kuosa, 2000). We have sought for a solution to that communication problem by constructing a virtual prototype which aids in making users' work visible. The idea is that, instead of just describing their evaluations of a design, users' can also show how they would do their work tasks with prospective machine. This idea is, on one hand, based on IS development and making work practices visible (e.g., Suchman, 1995, Simonsen and Kensing, 1997) and, on the other hand, on the potential of walk-in virtual environments (VEs) (Särkelä et al., 2009, Koutsabasis et al., 2012).

In our study, IS research is seen as a design science (based on Hevner et al., 2004), the purpose of IS research being to answer to the needs of practical reality, i.e. people's and organizations' needs. We attempt to find out how to overcome the communication problem between users and designers and seek the practical answer with developing a virtual machine prototype. This paper focuses whether users find the prototype so immersive that they can do their work with it. Following the guidelines of the design science, we construct and evaluate an artefact by utilising a scientific knowledge base (on co-creation and participatory IS development) and simultaneously adding new knowledge to the base.

The practical problem to which we aim to seek an answer in a multiphase study process is the co-operative design of mobile work machines, especially their control cabins. These cabins are complex entities in forest and mining machines for highly specialized purposes. The machines that are produced in small series are human-driven. Concurrent engineering is often needed because typically the machine and its control cabin are designed by different engineering teams. In this case, machine drivers and the mechanics are the product users. To make it easier to control the machines in a coherent and transparent manner and to provide a flexible working environment for the drivers in the cabin, their knowledge is used in the design process. Mistakes add to work time and may harm the machine, though the drivers do not make them if the cabin is well designed. Also the mechanics' knowledge is needed in the design process to make the parts which need installations and maintenance easier to access. We have earlier made some tentative studies about using VE in product design from both product designers' and product users' point-of-view (e.g., Kuusisto et al., 2012). As they are promising we now started to study the idea systematically. This paper presents the first step of this research process: it focuses on how product users can do their work tasks with the virtual prototype, especially which technical feedback components are essential in such case.

This paper is structured as follows: first the scientific knowledge base on which the artefact is constructed is outlined. The knowledge base has information about research on user participation in IS development and making work visible there and also includes product co-creation studies. In Section 3 the constructed co-creation tool is outlined. The tool, VIP2M, is a virtual environment for prototyping a mobile working machine. The drivers of the machine can evaluate it, and the designers can observe how the drivers use VIP2M and how they talk about it later. Apart from constructing an artefact, a design science study should include its evaluation (Hevner et al., 2004). We evaluated the usefulness and immersivity of VIP2M with user tests. For finding an adequate level of VE components, we compared three alternative setups. The test users, procedure, data gathering and results are described in Section 4. In Section 5 our study is discussed, in accordance with the guidelines for design science in IS research by Hevner, March, Park, and Ram (2004). At the end of the paper, we make a concluding remark of the promising results in using VIP2M for making users' work visible for the design process.

2 Knowledge Base about Product Users' Participation in Design

User participation in the design process has a long tradition, but there is some disagreement about the exact extent of user involvement needed in the design work. On one hand, users are considered as informants who can supply facts about work procedures but who have hardly any design knowledge and. therefore, should have little to say about particular design issues (Olsson, 2004). Users stay in their own competence area, and designers' task is to understand them and collect information for the design process (Steen, 2011). Here this approach is labeled *Designers' move towards users* (Table 1). On the other hand, there may be user representatives who participate for years in design projects and learn the design practice. In that case, there is a risk that users become professional design experts and neglect the maintenance of their work expertise. (Olsson, 2004.) Thus, users are expected to participate in the design process and know how designers think and work. Here this approach is labeled *Users' move towards designers* (Table 1) (Steen, 2011). Besides of dividing the human-centred approaches to actors' roles (whose work is focused and who is asked to be flexible), they can be divided by their focus on either presenting the present situation (*what is*) or future situation (*what could be*) (Steen, 2011).

Co-operation focuses on…	**Designers' move towards users**	**Users' move towards designers**
Concern for *what could be*	Co-Creation	Co-design
↕	Contextual design	Lead user approach
Concern for *what is*	Ethnography	Participatory design

Table 1. Different human-centred design approaches, with different starting points and emphases (based on Steen, 2011).

Some human-centred design approaches focus on users moving towards designers. **Participatory design** aims to give future users of a computer system a role in its design, evaluation and implementation. Participatory design has its roots in the 1970s in Scandinavia and was initiated by academics that cooperated with people from trade unions. (Ehn, 1988, Greenbaum and Kyng, 1991). **Lead user approach** is based on the observation that many ideas for new products originate in minds of innovative users and do not always come from professional designers. The lead user approach differs from participatory design by its orientation: the lead user approach is typically oriented towards commercial and business concerns, whereas participatory design is typically oriented towards concerns for democracy and emancipation. (Steen, 2011.) **Co-design** can be understood as an attempt to facilitate users, researchers, designers and others in creative cooperation, so that they can jointly explore and envision ideas, make and discuss sketches, and tinker with prototypes. In co-design, 'everyday people, rather than customers and users, are the participants and co-creators who contribute as 'experts of their experiences'. Co-design and participatory design have different starting points: in participatory design one can involve a group of people who currently work together and keep to their current practices (*what is*), whereas in co-design one can invite people who have never met before and start with an idea for a novel technology or a putative opportunity (*what could be*). (Steen, 2011.)

Some other design approaches focus on opposite perspective; designers moving towards product users. Also these types of approaches can have different aims based on their focus on the present situation (*what is*) and future possibilities (*what could be*). **Ethnography** focuses on the present situation. In it one attempts to look at naturally occurring situations holistically and from members' point-of-view. Holistic observation here means that researchers and designers look at how people and their actions are embedded in social and cultural context. (Simonsen and Kensing, 1997, Steen, 2011.) Ethnography has been used in IS development from the 1980s to address some of the problems encountered when using interviews in requirement analysis to find out about user needs. The problems include misunderstandings which are based on users' and designers' different underlying assumptions (e.g., Davidson et al., 2001, Luck, 2007), unstructured users' contributions, which include a mix of needs, suggestions, conditions, and problems (Bergvall-Kåreborn and Ståhlbröst, 2010), as well as the problem of allowing only some issues a say in our social milieu (Suchman, 1995). In the IS field, software development and evaluation for teamwork (Galegher and Kraut, 1990, Orlikowski, 1992) have been the early users of ethnography and proponents of making work visible.

For our purposes ethnography is useful as it focuses on people's actions in context. We aim to create a tool with which workers' work tasks can be observed. However, ethnography focuses on *what is* whereas we aim to create a tool which focuses on *what could be*. **Contextual design** is towards future products. It draws from ethnography and participatory design and is intended to help researchers and designers to observe people in a (work) context, to discuss their observations in a multi-disciplinary product development team setting, and to translate these observations into specifications for a new product or service. (Steen, 2011.)

Co-creation (originally, Emphatic design in Steen, 2011) provides designers access to users' experience of their material surroundings and the people in it. The term co-creation is based on the idea that consumers are active players who are co-creators of value and co-developers of their own personalized experiences (Prahalad and Ramaswamy, 2000). We shape the term co-creation into work context, when it means that a product user is able to personalize his/her experience to a level that is best suited to get his/her job done. Co-creation differs from ethnography by its focus *on what could be*. Furthermore, co-creation and co-design can be seen as different ways to bridge the gap between the world of designers and the world of users. In co-creation customers are seen as active players, so active dialogue with them is essential. For that the Internet is widely used, as mobilizing customers to use Internet chat rooms and consumers' self-selecting virtual communities (Prahalad and Ramaswamy, 2000). Besides of discourse-oriented methods also more collaborative and design-focused, methods have been used to get users to think about a novel way regarding their future practice: e.g., role-playing (Steen, 2011), scenarios (Bødker, 2000) and visual images (Bratteteig and Wagner, 2010). It is necessary to consider the ways of creating trial use situations as part of the design process, so as to stage users' hands-on experience with the future (Bødker, 2000).

Instead of discourse, we focus on methods with which users can show their actions with prospective products, as tasks include tacit knowledge which presenting in verbal form is hard or even impossible. To take users' involvement to the early phase of the product design process, low-fidelity prototypes are used. Low-fidelity prototypes, such as sketches drawn on paper, are produced quickly and with a low cost, and thus they can be used in early phases of the design process (Yang and Epstein, 2005). When users test several low-fidelity prototypes, designers obtain more critical comments, which help to identify problems throughout the design process (Tohidi et al., 2006). Besides of paper sketches, also virtual prototypes can be used. They represent the design concept through a detailed computer simulation and may be more realistic than drawings (Yang and Epstein, 2005). Virtual prototyping enhances the effectiveness of high-fidelity prototyping because it can be faster and cheaper than physical prototyping. Virtual prototyping allows simulations and quick changes to the prototypes.

3 Constructed Co-Creation Tool: VIP2M

One part of the design science in IS research is the construction of an artifact. We created a co-creation tool, which supports the co-creation approach by showing how workers work with the tool that is under design. The tool is VIP2M in a walk-in VE. Making drivers' work visible to designers gives an illustrative starting point to drivers' and designers' mutual discussions. Our solution differs from the earlier ones by focusing on how drivers' will work with the machine that is under development; in our case the machine is simulated in VIP2M. Furthermore, one benefit of using VIP2M is that the machine prototype can be changed quickly and several alternatives can be tried, which also supports creativity and mutual understanding.

Walk-in VEs, such as cave-like environments, are enabling technology for co-creation. Influenced by interactivity and media richness, virtual worlds can increase telepresence or, shortly, *presence* (e.g., Steuer, 1992). Presence is often defined as a subjective experience of being in one place while physically situated in another (Suh and Lee, 2005). When a subject gets immersed in a VE, the medium providing the virtual world disappears from the conscious attention of the subject. This creates a perceptual illusion of non-mediation, i.e. presence. Presence can also be seen as resulting from interaction between a person and the environment. In our case, interaction with the synthetic world offers the subject a feeling of immersion, and the world of the computer becomes the world of the user (Coelho et al., 2006). In walk-in VEs, the sense of presence for the users is generated with different methods of sensory feedback known as the immersive components of VEs. A basic immersion component is a stereoscopic three-dimensional (3D) view. Besides of 3Dview, also sounds and different haptic and tactile displays are common immersion components.

We have made some tentative studies about using VE for product design. Our study about consumers' interpretations of furniture prototypes in VE presented that some consumers focused on VE technology but some of them focused on the objective, i.e. furniture, design and interior (Kaapu and Tiainen, 2010). Also we have made an action research of making a VE tool for machine design (Kuusisto et al., 2012). Within this process we observed together with designers how machine drivers' acted with virtual prototype and encountered that sometimes designers were surprised about the drivers' actions. Our earlier experience on the studying the virtual machine prototypes encourage us to continue the study line. We decided to do it now structured and from all perspectives.

Figure 1. An outside view of the loader which was prototyped in VIP2M.

Figure 2. A view from inside the loader through VIP2M.

For our study, VIP2M was simulating a heavy loader used in underground mines (Figure 1). Its design process benefited from the practical work knowledge of drivers and mechanics. VIP2M is useful for making work visible, although, to the driver of the simulated machine, it *only feels* like a real machine in an authentic environment. This can be measured by evaluating the feeling of presence generated for the user driving VIP2M.

The technical environment which we used in the implementation of VIP2M is a walk-in VE. It consists of a three-wall rear-projection based system. It takes advantage of active stereo projection and optical head tracking, which is implemented with markers on the shutter glasses and 6 cameras. The audio environment comprises a 5.1 sound system. An essential part of VIP2M is the pneumatic motion platform with six degrees of freedom.

In the real loader the cabin is tiny. The driver sits sideways facing to the right side of the machine and s/he must turn his/her head left when driving forward and right when driving on reverse. The VE's three walls are straight-angled, which makes it quite immersive. The awkwardness of the driving position is increased by the very limited view outside from the cabin (Figure 2). Especially the view forward is very constrained due to the large bucket, which blocks the line of sight almost completely in certain positions. Due to these kinds of factors, it is extremely important to have the eventual user of the machine take part in the design process.

To make VIP2M more realistic, there are some physical parts from the real cabin. The driver chair is similar to the chairs used in mining machines. Also the control joysticks correspond to actual controls of a loader. With the left joystick, the driver selects the driving direction and current gear as well as controls the orientation of the body of the machine. The right joystick is used for controlling the boom and the bucket. Most of the controls of the actual machine are present in VIP2M. However, the gas and brake pedals are electric, whereas in a real machine the brake is hydraulic. The control panel of the machine is a virtual one. It contains a display, which provides the driver with information about the state of the machine (e.g. driving direction, current gear, and revolutions per minute, RPM).

4 Evaluation of VIP2M

In design science type IS studies, once the artifact is constructed, its usefulness needs to be evaluated. Our target is to study how VIP2M fits to our targets from several perspectives. First, studying product users' point-of-view question: How can users use the product prototype via the tool (that is this paper's focus)? We aim to study later designers' point-of-view (as how do designers interpret users' acting with the prototype) and finally, when VIP2M is developed enough good based on the earlier research focuses, we will study its usefulness in design co-operation.

In this paper we focus on the first part, which focus on product users' (i.e. machine drivers') presence feelings while they are acting with VIP2M. That is whether the user can get a feeling of presence that would make him/her behave with VIP2M as if it were the actual machine. We organized user tests to explore users' success in the driving task and their feeling of presence. As 3D VE affords a higher sense of presence than 2D VE (Nah et al., 2011), we made comparisons between them in our study. Furthermore, as the flow experience allows people to focus on their actions and produces high feelings of presence (Csikszentmihalyi, 1975, Särkelä et al., 2009), we evaluated the effect of the motion platform on the increase in the feeling of presence. Thus, in the test use, we compared three alternative VE setups.

Besides of comparing the three alternative VE setups, we also compared machine drivers' presence feelings to the feelings of those who have never driven a heavy work machine. When their earlier experience differs, they have different reference point, so also their VE experience might be different. As we need to compare two dimensions (the type of user and the immersion of VE setup) we decided to use quantitative research methods. However, taking users to VE visit is time-consuming, so the number of test users must be low. For getting comparable data we used to methods in gathering data. First, the task performance of test users with different setups was measured. Second, a fill-in questionnaire was used for outlining test users' own evaluations of the presence level.

4.1 Users in the Test

Since experience and familiarity with technology affects the generated sense of presence (Lee 2004), we wanted to find test users with different levels of experience and knowledge regarding the work task of the prototyped machines. We expected that some of the test users would have some earlier experience from driving heavy work machines and some others should have none. We searched for test users among university students as well as students and teachers of occupational updating training.

The test group consisted of 25 males, aged between 17 and 59 years, the average age being 30 years. All the test users had a normal or corrected-to-normal vision. The test users were categorized to

Drivers and *Non-Drivers*. This was done based on their own answer to the question: *How often do you use or have used large, mobile work machines such as tractors or harvesters?* Those who answered *never* or *tried sometimes* were labeled as *Non-Drivers*, and those who answered having used mobile work machines *a couple of times a month* or more were labeled as *Drivers.* A total of 15 test users belonged to the Drivers category and 10 to non-drivers.

4.2 Test Procedure

As the aim was to evaluate whether VIP2M creates the presence feeling in its users, we made different combinations of the immersive components. The first setup of VE immersive components – labeled *Plain* – included only a 2D visualization in three walls. The second setup, *Visual,* included a 3D stereoscopic view and head tracking. The effect of head tracking is that the virtual view is coordinated with the movement of the user's head. In VIP2M, the head tracking enables the driver to peek outside, through virtual windows, to see an object that would otherwise be blocked from view. The third setup was labeled *Moving* and included everything of the Visual setup and also the motion platform.

We split the test users to two groups so that each test user performed two test drives with different setups. The first group performed the first drive with the Plain setup and the second drive with the Visual setup. The second group performed the first drive with the Visual setup and the second with the Moving setup. All in all, 15 drivers and 10 non-drivers participated in the user tests. Due to technical problems automatic measurement by VIP2M did not work in five test drives, and those test drives had to be taken out from the analysis. Finally, six drivers used the combination of Plain-Visual and five test drivers Visual-Moving; of non-drivers only three did the Plain-Visual and six the Visual-Moving drive.

The test was done individually. First, each test user got an introduction to the use of VIP2M and its controls as well as to the task they were asked to do with VIP2M. At the beginning, the test users saw the loader and the movements of the boom and the bucket from outside (Figure 1), because the view from the cabin was so limited that to understand how the boom and bucket move would have been very hard that way. After introducing the VIP2M actions, the test users were allowed to drive freely for few minutes to get a feeling of VIP2M and its controls.

1. How much were you able to control events?	Not at all		Reasonably			Perfectly	
	1	2	3	4	5	6	7
2. How responsive was the environment to actions that you initiated (or performed)?	Not at all		Reasonably			Perfectly	
	1	2	3	4	5	6	7
3. How compelling was your sense of objects moving through space?	Not at all		Reasonably			Perfectly	
	1	2	3	4	5	6	7
4. How inconsistent or disconnected was the information coming from your various senses?	Very incons.		50% consist.			Very cons.	
	1	2	3	4	5	6	7
5. How much did your experiences in the virtual environment seem consistent with your real-world experiences?	Not at all		Reasonably			Perfectly	
	1	2	3	4	5	6	7
6. How completely were you able to actively survey or search the environment using vision?	Not at all		Reasonably			Perfectly	
	1	2	3	4	5	6	7
7. How much delay did you experience between your actions and expected outcomes?	Very much		Some			None	
	1	2	3	4	5	6	7
8. How quickly did you adjust to the virtual environment experience?	I did not		After a while			Immediately	
	1	2	3	4	5	6	7
9. How much did the visual display quality interfere or distract you from performing assigned tasks or required activities?	Very much		Somewhat			Not at all	
	1	2	3	4	5	6	7
10. To what extent did you feel like actually being in a mine?	Not at all		Somewhat			Completely	
	1	2	3	4	5	6	7

Table 2. Questionnaire for evaluating the user's presence level.

Each test user drove two test runs. The driving task in each test run was the same: the driver was supposed to drive into a pile of rocks, load as many rocks as possible in the bucket, drive a few hundred meters to the unloading zone, and empty the bucket. The driving task included driving in both directions and making some sharp turns in narrow mine corridors. The combination of narrow corridors and a limited view from the cabin made the driving task quite challenging, resembling the conditions in reality. In defining the test use, our purpose was to make the driving task as realistic as possible. Task performance was evaluated by measuring the time taken for the driving task, the amounts of rock loaded in the bucket and unloaded at the end (these might differ due to dropping of some rocks while driving), and the number of times the virtual loader collided with the mine walls.

After each run, the test users evaluated the level of presence with a questionnaire. The questions were picked from the Presence Questionnaire (Witmer and Singer, 1998), as it is a well-known method to evaluate presence. Only the questions that fit well the VE, VIP2M and task in these experiments were chosen. The last question (Table 2) is not from the Presence Questionnaire, but it was added to find out how realistic the user's feeling of actually being in a mine was. A Likert-type seven-point-scale format was used. The results were analyzed by averaging the scores of each driver and non-driver. The statistical significance of the results was examined with one-way between-subjects ANOVA.

4.3 Results of User Test

The results of the user test show whether VIP2M gave the feelings of presence and whether there were differences between different immersive setups or between the users based on their earlier driving experience. The summary of the analysed data is presented in Table 3. The first columns present the type of users and the setups which they used in driving tasks: first there is a division based on users' background to drivers and non-drivers, followed by the number of test users and the name of the setup of VE immersive components.

Test groups	#	Setup	The amount of rock		Hits		Presence	
			into bucket	transported	AVG	STD	AVG	STD
Drivers	6	Plain	3880	3550	0.5	1.2	4.5	1.4
		Visual	3570	2490	7.5	4.4	4.6	1.5
	5	Visual	3720	3720	7.8	5.6	4.9	1.2
		Moving	5020	4350	13.0	15.1	5.6	0.9
Non-drivers	3	Plain	3940	3850	2.3	1.2	5.0	1.5
		Visual	4320	4100	6.3	5.0	5.6	1.2
	6	Visual	1700	1480	10.7	10.8	4.8	1.4
		Moving	2010	800	8.8	10.5	5.3	1.4

Table 3. Summary of user test results.

The next two columns (labelled *The amount of rock* and *Hits*) present the data that was collected by VIP2M. The first number in the amount of rock shows how much rock the driver got into the bucket and the second number how much s/he transported to the unloading zone (some of the rock fell off during the drive). These numbers show that drivers with the Moving setup got the most rock whereas non-drivers with the Moving setup the least. It seems that activating the motion platform helped the experienced drivers to load rocks, while inexperienced drivers found the work just as hard as with the Visual setup.

The other variable which was measured by VIP2M was Hits, which contains the average number of times the loader collided with the mine corridor walls. The collisions with the bucket as well as those of front and back parts of the machine body were detected and summed together. Naturally, each time the machine bumps into a wall, dozens or hundreds of collision data points are usually generated. Successive collision data points were considered as belonging to the same collision event. Thus each number indicates a distinct event. Besides of the average (AVG) also the deviation (STD) was calculated. These show that the number of hits increased with the number of immersive components. This means that the driving task became more difficult as VIP2M became more immersive. Also the time of driving was measured, but as the test users were not told that they should do the tasks as quickly as possible, the analysis of time is not meaningful.

The last column (Presence) presents the average results for the questions concerning user's presence level (questionnaire in Table 2**Error! Reference source not found.**). From the results we see that the switch from the *Plain* setup (2D view) to the *Visual* setup (3D view with head tracking) did not significantly affect the generated sense of presence. On the other hand, the *Moving* setup (i.e. activating the motion platform) did increase the feeling of presence. The differences are bigger within drivers. This is remarkable since having earlier experience on driving heavy machines they can compare their VE experience to a real one.

The user test of VIP2M indicates that the prototyping machine, in addition to a visual image, also needs to have a moving platform for its drivers. The differences between experienced and inexperienced users appear only with the *Moving* setup, especially with the amount of rock. Furthermore, the feeling of presence increases in the drivers' group when the moving platform is activated. It seemed relevant to the test users that they felt the movements of VIP2M. Based on these results we suggest that realistic movement of the prototype creates a strong feeling of presence. So, keeping in mind the limited resources we have for developing VIP2M, a moving platform is probably a better investment than improvement in the resolution of graphics.

Both drivers who have experience on driving a real machine to which compare the virtual one, and non-drivers without such experience participated to user test. The results presents differences between drivers' and non-drivers' feelings of presence in using VIP2M. The differences are a good point, as it presents that earlier experience effects on the driving experience with VIP2M.

5 Discussion

This paper presented a design science IS study about creating and evaluating VIP2M. It was created to support product users, as the mobile work machine drivers' participation in the product design process indicates, so that they can present how they would do their work tasks with the prospective product. In this paper, we have outlined what VIP2M is and how it is evaluated. Now we discuss the results based on the guidelines for design science in IS research by Hevner, March, Park, and Ram (2004).

The first guideline states that a design science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation (Hevner et al., 2004). In our case, VIP2M was constructed. It is a VE construct and includes a VE application with physical components. The constructed VIP2M is an outline, sketching researchers' idea of a co-design tool to a concrete level. It was made for research purposes and for the visualisation of the idea. Further development is needed before taking it to business use for co-design work. The development work continues in a spin-off company of our research project.

The second guideline states that the objective of design science research is to develop technology-based solutions for important and relevant business problems (Hevner et al., 2004). In our case, the organizational problem to which a solution is searched, is a co-operative design, in which product users can participate, based on their own experience and knowledge. The business case which we studied was the design of mobile work machines and their cabins, and the users whose participation in the design process was requested were machine drivers. We needed to develop a tool and a co-creation method in which machine drivers can participate temporarily and without any design education. Our solution was a method which belongs to the co-creation approach and which includes a tool, VIP2M, with which the drivers can show how they will work with the product under design.

However, at the moment we are in the beginning with shaping the solution to the business problem of co-creation. The development of the tool VIP2M which supports co-creation with product users is just one part of finding the solution to business problem. The other part is to change the design process so that there is space for product users' (i.e. drivers') experience. Co-creation research literature (e.g. Prahaland & Ramaswamy 2000) deals partly this problem, but there is still considerably to do with it. We continue that work in the future steps of VIP2M development.

The third guideline states that the utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods (Hevner et al., 2004). In evaluating VIP2M we used controlled experiment. In the user test, 25 test users (drivers and non-drivers) performed a driving task with VIP2M. Their successes in the tasks were measured, and their own evaluation of the presence was asked and analysed. However, this kind of user test outlines only one aspect of the tool. For opening wider picture interviews about users' experiences with the tool and designers' interpretations of virtual prototypes are needed. We continue the study and focus later also qualitative studies.

The fourth guideline states that effective design science research must provide clear and verifiable contributions in the areas of design artifact, design foundations, and/or design methodologies. An IS design study can give three kinds of research contributions: most often the contribution is an artifact itself, but then the artifact must enable the solution of unsolved problem. The other possible contribution is a creative development of novel, appropriately evaluated constructs, models, and methods of instantiations. The third possible contribution is a creative development and use of evaluation methods and new evaluation metrics (Hevner et al., 2004).

In our case, the contribution is the designed artefact, VIP2M, which includes both application and physical tools in a walk-in VE. VIP2M makes is possible to users (i.e. machine drivers) to try how they could do their work tasks with the machine that is under development. The ideas of VIP2M give a basis for the development of a co-design method for a novel solution on how product users can participate in the product design process from the users' own perspective. This kind of solution makes it possible that users' expertise gets some space within product design process; this solution overcomes communication problems which are based on differences in users' and designers' underlying assumptions and language. However, this is a start of a research and development line and just the future will show if it will be fulfilled.

The fifth guideline states that design science research is derived from the effective use of the knowledge base of both theoretical foundations and research methodologies (Hevner et al., 2004). In our case, we utilized knowledge about different types of human-centred design approaches, especially of the co-creation approach. Furthermore, we used the research tradition of the methods of controlled experiment and statistical data analysis in our test use.

The sixth guideline states that the search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment (Hevner et al., 2004). The design of VIP2M includes several iteration rounds, which include several evaluations, as well. The development and evaluation continues.

The seventh guideline states that design science research must be presented effectively both to technology-oriented as well as management-oriented audiences (Hevner et al., 2004). The results have been presented during the research to the business partners, but the scientific publishing of the results is just in the beginning. The technical side of VIP2M has been presented to the VE research community (Kuusisto et al., 2011) and to the machine design community (Kuusisto et al., 2012). This paper focuses more on the human-centred design directed to the academic IS community.

6 Concluding Remark

This paper is the first step in a research line which aim is to support product users' participation in product design process. The theoretical base is co-creation, which is a design-oriented approach focusing on *what could be* and provides the space for workers' participation with their own expertise (e.g., Steen 2011). Traditionally co-creation research focuses on discourse with customers, for example, via Internet chat rooms (Prahalad and Ramaswamy, 2000). However, some work cases include lots of tacit knowledge, which workers' cannot present in verbal form. For this situation we created a tool, VIP2M, which enables product users to experiment working with the product under design.

In this paper we presented the first step, which outlined experienced and non-experienced drivers' testing alternative VE setups of mobile work machine. This was done for finding the immersion level of VIP2M which is enough to create drivers' presence feeling, which is needed for users to behave as they were acting with a physical tool. Our user test indicated that besides of 3D stereoscopic view especially motion platform is crucial when a design of moving work machine is prototyped in VE. The test expressed the significance of moving platform in two ways: experienced drivers made the best transporting results with it and their presence feeling was clearly higher with that setup.

Our user test of VIP2M presented that product users (in our case, machine drivers) have a presence feeling, which enable their behaving similar than with physical tools, for example, using their work skills with virtual prototype. We suppose that these findings are possible to generalise to other similar kinds of VEs. The result of our user test is promising for using the VE tool for showing how product users would do their work tasks with the prospective product. This means a new solution to communication problem which complicates users' participation to product co-creation. We aim to continue to study the usefulness of VIP2M in co-creation. We have presented VIP2M to collaborative mobile work machine companies and we have got promising feedback from designers. The next research step will be studying how designers' understand workers' actions with VIP2M and what benefits they see of using VIP2M in product design. The final step will be using VIP2M in actual machine design process. It is promising that we can to carry out those steps as we already have collaboration with machine companies. Furthermore, during constructing VIP2M some researchers of our team created a spin-off company for continuing development and productisation of VIP2M.

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