User evaluation of Industry 4.0 concepts for worker engagement

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Abstract. Industry is undergoing a digital transition that will change the design and setup of human-machine systems. One part of this change is increasing possibilities of workers to influence their work. In this paper, we present four components of the Factory2Fit project that contribute to this change by engaging workers: (1) knowledge sharing and collaboration via a discussion platform; (2) visualisation of information via augmented reality (AR) glasses; (3) participatory design of workplaces and tasks by means of a 3D simulation software programme, and (4) an on-site training tool utilising a training platform. The demonstrators were evaluated with workers to identify foreseen benefits, challenges and impact on their work. Most of the concepts seem to be well accepted and they have high potential to improve work well-being and work performance. The results of this study are encouraging, but long-term field studies with actual prototypes will be needed to evolve the concepts.

Keywords: Industry 4.0 · Acceptance · Engagement · Work · Manufacturing · Smart Factory

1 Introduction

Human-centricity is vital for engaging workers in smart factories. European Factories of the Future Research Association [1] see that industry is undergoing a digital transi-

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tion that will change the role of humans and machines. In the future, tasks will be performed in cooperation between knowledge workers and smart manufacturing technologies. Workers need to be supported at their workplace when adapting to upcoming digitalisation and cooperation requirements. This support to the workers can be given efficiently by utilising innovative digital technologies.

Human-machine interaction needs to be inherently safe. Open innovation and product co-creation by scaling knowledge from the shop floor, and knowledge sharing and creativity with global engineering teams are highly important. New digital technologies should open new possibilities for the workers without hindering the usage of professional abilities the workers already possess.

This study is conducted within the EU-funded project Factory2Fit. The project is developing adaptive, empowering and engaging factory floor solutions, which aim to improve both productivity and work well-being. The goal of the study is to identify conceptions that workers have regarding the proposed concepts to engage workers. In addition, foreseen benefits, challenges and forms of impact are studied.

2 Material and methods used for the study

2.1 Concepts for engaging workers

The first concept is knowledge sharing and collaboration via a social media platform (later SoMeP). Its goal is to increase knowledge sharing among workers and to support them in problem solving situations. SoMeP is a software that can be used in the factory via smartphones, tablets or PCs. It provides the options to share messages, photographs and videos. The added value to existing solutions comes from linking the discussions with production-related information (e.g., discussions related to a specific error code).

The second concept is the visualisation of information via augmented reality (AR) glasses (later AR-tool). The purpose of this concept is to provide context related information at the workplace. AR glasses (e.g., Microsoft HoloLens) can be used to display interactive interfaces on real and digital augmentation targets, e.g., point towards the location of an alarm. An AR-tool could also visualise information from other software, for example, the SoMeP.

The third concept is participatory design by means of 3D simulation software for workplace and task simulation (later 3D-PD). The goal of this concept is to provide workers the possibility to co-design the workplace and plan working practices with other stakeholders. The 3D simulation software (Visual Components) supports the design of workplaces and work tasks.

The fourth concept is the on-site training tool utilising a training platform (later training tool). With machine-learning based search and retrieval algorithms, the worker can find relevant and focused instructions in video format. The purpose is to provide support and teach work tasks on-site. It can be used with tablets and smartphones (Fig. 1).

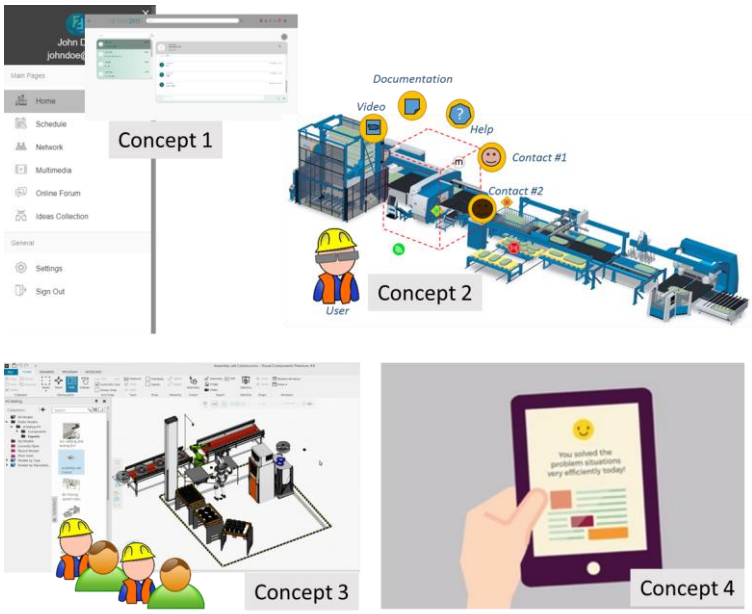

Fig. 1. The four concepts introduced in Factory2Fit to increase worker engagement.

2.2 Methods applied in the study

Two workshops were conducted to discuss the four concepts of engaging factory workers. One workshop was held at a machinery manufacturer in Finland and the other in a metrology lab of a components manufacturer in Germany.

Eight male participants took part in the workshop in a Finnish company. Their average age was 46 years (range 33-55 years). The group was comprised of one automation designer, two engineers, a production supervisor, a quality expert, an electrician, an automation assembly worker and a worker with responsibilities during the start-up of the machine. Their experience in their current work role was 13 years on average (range 5-33 years). As a whole, the participants were well familiar with the digital technology related to smartphones, tablets and navigators, but were quite inexperienced regarding newer technology (e.g., AR technology).

Eight participants (six male and two female) took part in the German workshop. The work of the participants was mainly related to quality-control tasks in a metrology lab. This group was comprised of two measuring machine operators, two shift supervisors, two mechanics, and one quality controller. One participant's role was undisclosed. Their experience in their current work role was 4 years on average (range 0.2-18 years). The level of knowledge and experience of digital technology was roughly the same level as the previous group.

First, the project was introduced on a general level to the participants and they signed consent forms and answered the demographics questionnaire. Then, the four concepts were introduced briefly one by one. In the first workshop, the AR tool concept was demonstrated with HoloLens, but workers did not want to have a hands-on experience about it. Other concepts were illustrated with slides, photos and videos. In

the second workshop, all concepts were illustrated with slides, photos and videos without actual hands-on experience.

After the presentation, workshops were conducted with researchers as facilitators. Firstly, each participant filled in the questionnaire regarding his/her experience of the concept by using a 5-point Likert-scale. Thereafter, the concepts were discussed in the group. In the first workshop, discussions were conducted in two groups: factory floor workers (three persons) and other stakeholders (five persons), whereas in the second workshop, all participants discussed together in a single group. Discussion themes were benefits, challenges and improvement ideas of the introduced concepts.

Data analysis was based on the Factory2Fit Work Well-being Framework [2], which was developed in this project. In this study, user experience, user acceptance and safety were addressed from the framework.

3 Results

In the Finnish workshop, participants liked the SoMeP. They thought that it would be useful in knowledge sharing, for example, between shifts. With this concept, all information would be stored in one place, which was found to be an important benefit. However, they thought that the co-existence of different languages and conversation groups (local vs. global) might become a challenge. As a practical drawback, the participants wondered how the information would be managed if there is lots of it. Furthermore, some people may be reluctant to write messages with their real names. They also suggested that other information could be added there, e.g., supply schedules and the status of backorders.

The participants saw potential in the AR-tool when used in training and maintenance, e.g., providing visual instructions while the maintenance worker is using both hands for the task. The discussions revealed workers' concerns on occupational safety. They proposed that AR equipment should be chosen based on workplace conditions. This would ensure that the workers always have a clear view of their immediate surroundings, and the device materials can withstand the environmental conditions (e.g., heat). These concerns naturally affected user acceptance (**Table 1**).

The participants thought that the 3D-PD is a nice concept and should be used, for example, when designing assembly. By using the tool, it is possible to foresee problems and everyone can participate. On the other hand, they thought that the tool would be used rarely and that it might be difficult to find consensus over many differing opinions.

The training tool received many positive comments: it was found to be practical, the logic is clear and the participants assumed it functions well and is easy to use. They saw benefits for novice workers, and that the image- and video-based tool would not have any language barriers. It would speed up the work. As a challenge, they saw the efforts needed in creating and maintaining video content. As a new invention, they considered that this tool could be used to identify parts that are missing identification codes.

Table 1. Questionnaire results from both workshops (5=strongly agree/strong positive experience; 1=strongly disagree/strong negative experience).

	Workshop 1 (N=8)				Workshop 2 (N=8)			
	SoMeP	AR-tool	3D-PD	Training	SoMeP	AR-tool	3D-PD	Training
	AVG (STDEV)	AVG (STDEV)	AVG (STDEV)	AVG (STDEV)	AVG (STDEV)	AVG (STDEV)	AVG (STDEV)	AVG (STDEV)
In general, how did you feel about the tool	3.63 (0.74)	3.63 (0.74)	4.13 (0.83)	4.38 (0.52)	3.43 (0.53)	2.57 (1.13)	4.86 (0.38)	3.43 (0.79)
Using the tool would make the job of factory worker more enjoyable	3.63 (0.52)	3.25 (0.46)	4.25 (0.71)	4.63 (0.52)	3.25 (0.46)	2.50 (0.93)	4.75 (0.46)	3.50 (0.53)
Using the tool would make the factory work more interesting	3.75 (0.46)	3.88 (0.64)	3.63 (0.74)	4.13 (0.83)	3.75 (0.71)	3.13 (0.64)	3.88 (0.35)	3.38 (0.52)
Using the tool would make the factory worker feel more competent at work	3.13 (0.83)	3.25 (0.71)	3.63 (0.74)	4.13 (0.64)	3.13 (0.83)	2.50 (0.93)	3.25 (1.04)	2.63 (0.52)
Using the tool could improve the performance of the factory worker	3.88 (0.35)	3.50 (0.76)	4.38 (0.52)	4.63 (0.52)	3.25 (0.71)	2.25 (0.46)	4.38 (1.06)	3.50 (0.53)
The tool would be well accepted among factory workers	3.13 (0.64)	2.88 (0.99)	4.00 (1.07)	4.63 (0.52)	3.13 (0.35)	2.13 (0.64)	4.50 (0.53)	3.25 (0.89)
The usage of tool in the factory floor would support safety	3.38 (0.74)	2.38 (0.74)	3.75 (0.46)	3.88 (0.35)	2.88 (0.83)	1.50 (0.53)	4.38 (0.74)	3.13 (0.35)

In the German workshop, the participants thought that the SoMeP could make sense in maintenance and as an error catalogue. If it were used with a tablet, it would be better available, compared to a PC, and without extra paperwork. However, they were concerned about the quality and correctness of the information and the amount of work it would take to add information. In the measurement lab, there is no time for extra work. There should be instructions and etiquette concerning how to add information to SoMeP and maybe not everyone should be allowed to add content.

The AR tool was considered useful in both maintenance and training applications. Similar to the Finnish workshop, the workers underlined the importance of solutions to be tailored towards ensuring occupational safety. In particular, situational awareness should not be hindered by the additional cognitive load of the holograms. This is again reflected in their respective scores shown in Table 1.

The 3D-PD was liked the most in the German workshop. The participants supposed it would help in planning the measurement room layout, enabling the trying out of different alternatives without stopping machines. The main concern was the amount of effort it may require to create simulations.

The experience of the training tool was positive. The participants said that it could be used in maintenance for simple disturbances. They agreed that the tool could be used to recognise parts which are around the workplace without identification information. Some concerns were related to the accuracy: if there are similar parts with only small variances, does the system identify them correctly?

4 Discussion and conclusions

The purpose was to identify conceptions that the workers have regarding the four concepts to engage workers including benefits, challenges and foreseen impacts on their work. The results of the two workshops in the two countries are somewhat similar and cultural differences were not observed. However, the differing nature of the

work tasks had an effect on their preferences; the quality control work with precision and detailed processes is different from manufacturing machines in general.

Based on the results, **user experience** of the concepts was positive. The participants agreed that most tools would make the work more interesting and enjoyable. The participants especially liked the 3D-PD and the training concepts.

Regarding **user acceptance**, most concepts were considered to become well accepted, indicating that as concepts, they would be accepted and possible issues, if any, relate to practicalities realized at the workplace. Presumably, as AR technology is not familiar among workers, its' acceptance was not as high as with other tools. However, based on the comments during the workshops, means to raise user acceptance were found, such as by pre-training users in the use of AR technology and by designing the tool in a manner, which supports occupational safety and situational awareness.

Some concepts were seen to improve **safety**. However, in the SoMeP concept, the moderation of the information was seen important to prevent sharing incorrect information, which could lead to accidents. Similarly, the image recognition in the training tool needs to be accurate to prevent the possibility of using false instructions. Safety issues were also raised in the AR use, indicating that increasing the field of view is needed to mitigate safety hazards.

Most of the concepts to engage workers seem to be well accepted and they carry a high potential to improve work well-being and work performance. The results of this study are encouraging and it was also possible to find remedies to the identified challenges. However, long time field studies with actual prototypes will be needed to develop the concepts further with actual users.

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