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D4.3 –Impacts of engaging workers to work design, training and knowledge sharing

FACTORY2FIT

Empowering and Participatory Adaptation of Factory Automation to Fit for Workers

Abstract

Smart factories are characterized by increasing automation and increasing customization. In these dynamic environments flexible and adaptive work organization is crucial, both for productivity and work satisfaction.

The Factory2Fit project will support this development by developing adaptation solutions with which people with different skills, capabilities and preferences can be engaged, motivated and productive members of the work community in manufacturing industries.

This deliverable describes the results of the co-design workshops that have been carried out during the Factory2Fit project. The goal of the workshops have been in defining, evaluating and improving the Factory2Fit participatory design, knowledge sharing and training solutions. This deliverable summaries these workshops and concludes the evaluation results regarding improvement needs and foreseen impacts.

Keywords: Participatory design, knowledge sharing, training, work engagement

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Executive Summary

The Factory2Fit project aims to developing worker empowering workplace adaptation solutions as well as engaging solutions for participatory design, knowledge sharing and learning. With the Factory2Fit solutions workers with different skills, capabilities and preferences can be motivated and be productive members of the work community. This will further improve work well-being and create safer and healthier work environment.

This deliverable is focused on the development of the engaging solutions for participatory design, knowledge sharing and learning. During the iterative co-design process six workshops were carried out. In the Workshop 1, first Factory2Fit ideas of the use cases were discussed and developed further. In the Workshop 2, use cases were discussed in practical level, considering industrial partners' needs. The Workshop 3 presented early demonstrations of the technical solutions. These were discussed and development suggestions were proposed. Consortium members took part to these three workshops. The Workshop 4 was held at the industrial partner Prima Power with their factory workers. The concepts were demonstrated and evaluated with the participants. The Workshop 5 was a replicate of Workshop 4 but it was held at Continental with their factory workers. The Workshop 6 included evaluation of the on-site training tool.

Based on the discussions in the workshops, engaging solutions were seen important when problems occur, new things need to be learned, and/or workers need to share their know-how of the work. In general, it can be said that participants' attitudes towards WP4 concepts were positive. They saw that especially concepts for knowledge sharing and on-site training would be useful in every-day work on a factory floor. However, they were concerned about the amount of work it takes to create content to the concepts and how information is managed.

Foreseen impacts of the concepts were that easy access to knowledge could improve the efficiency of the production due to short recovery time from challenging situations. In addition, the access to important knowledge and training information would improve work satisfaction and performance of factory workers. The participatory design, knowledge sharing and learning solutions will be developed further based on the evaluation results and integrated with other Factory2Fit modules for the industrial pilots.

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1 Introduction

1.1 Purpose of the Document

The purpose of this deliverable is to report results of the evaluation and impact assessment of WP4 solutions, which engage workers to design the working place, knowledge sharing and training. The deliverable reports the results of the workshops where WP4 solutions where iterative developed and evaluated until they are ready to be evaluated in the pilots of WP5. This deliverable will be updated M30. Then the focus will be more on the impacts of the solutions.

1.2 Intended readership

The deliverable is a public one, so in addition to sharing the evaluation results within the Factory2Fit consortium, we want to share the ideas also with a wider audience.

1.3 Relationship with other Factory2Fit deliverables

Six workshops that are reported in this deliverable are tightly connected to several Factory2Fit deliverables by providing material to them and applying material from them. Both the deliverable 1.2 *Industrial requirements* and the deliverable 1.3 *Adaptation concepts* have been formulised based on the discussions during the two first workshops. In addition, these deliverables have been used to guide the development work of WP4 solutions. The deliverable 1.4 *Adaptation architecture* has also evolved in the iterative co-design process. The deliverable 4.1 *Virtual factory platform* has gained important guidance from the workshop discussions. The evaluations in the Workshops 4, 5 and 6 were based on the Factory2Fit design and evaluation framework that has been described in the deliverable 1.5 *Design and evaluation framework and measuring tools*. The deliverable 4.2 *Engaging participatory design, training and knowledge sharing solutions* demonstrates WP4 solutions. The solutions were developed based on the findings from the three first workshops, and evaluated in the Workshop 4 and 5. Impacts are considered here also, but wide impact assessment is done in the deliverable 6.5 *Strategy and plan for the dissemination and exploitation of the project's results*.

1.4 Acronyms and abbreviations

Abbreviation	Description
AR	Augmented Reality
PD	Participatory design
UC	Use Case
WP	Work Package

Table 1: List of Abbreviations

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2 Co-design workshops

The purpose of the Task 4.5 *Co-design with stakeholders* was to develop engaging solutions by co-designing them with actual workers, industry experts and other relevant stakeholders. The aim was to refine and evaluate iteratively the solutions until they are ready to be evaluated in the WP5 pilots. Several workshops were arranged to develop WP4 solutions (participatory design (PD), knowledge sharing and training) with industry representatives and other project partners (Figure 1). The purpose of the workshops was to define ideas for WP4 solutions and develop them further. During the workshops use cases were defined in more detail, possible solutions were ideated and concepts were evaluated.

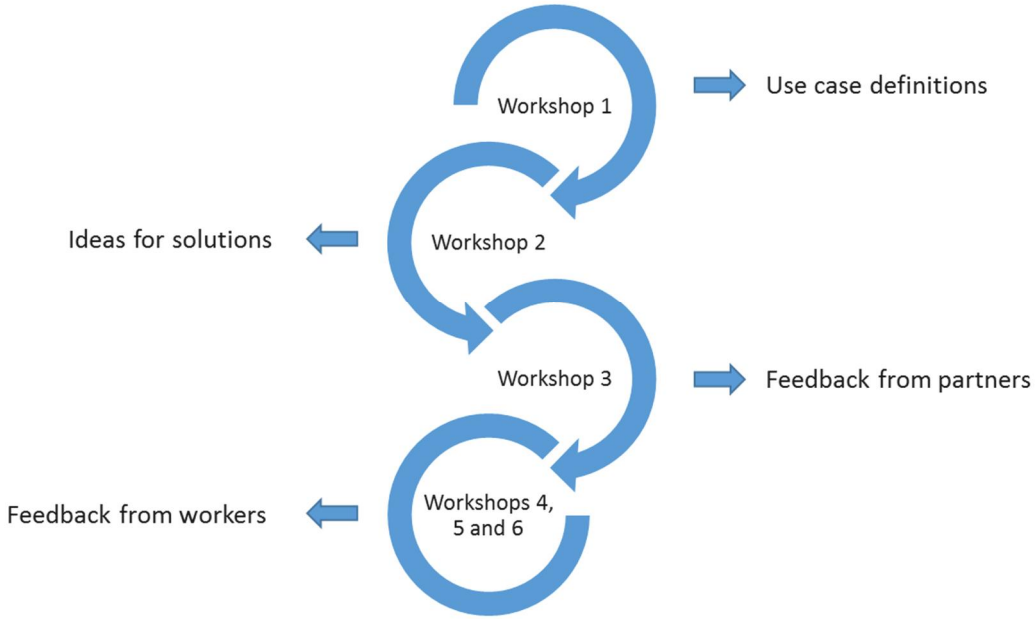

Figure 1: Iterative development of WP4 solutions.

Figure 1 describes the iterative development process with the six workshops and Table 1 lists the workshops' title, participants, place and time. Three workshops were arranged with consortium members in Finland, Ireland and Germany during 2017. In addition, a workshop was held with Prima Power's factory workers in 2018. The same kind of workshop was held also with Continental's factory workers. In addition, a workshop was held with factory workers from France (UTRC-I). The workshops and their results are described in the following sections.

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Table 2: List of workshops.

	Title	Participants	Place	Time
1	Workshop on Factory2Fit concepts	Consortium members	Espoo, Finland	7.3.2017
2	Workshop on WP4 topics	Consortium members	Cork, Ireland	31.5.2017
3	WP4 workshop - Early demonstrations	Consortium members	Chemnitz, Germany	18.10.2017
4	WP4 workshop - Concept presentation	Factory workers	Kauhava, Finland	6.2.2018
5	WP4 workshop - Concept presentation	Measurement lab workers	Limbach-Oberfrohna, Germany	14.3.2018
6	On-site training tool - workshop	Factory workers	France	March 2018

2.1 Workshop 1

The aim of the Workshop 1 was to develop further use cases (UC) identified by the industrial partners at the beginning of the project. These use cases where organized according to the Factory2Fit topics, adaptation, knowledge sharing, training and participatory design as following:

A. Adaptation:

   UC1: Role-based machine adaptationUC2. Allocation of workers to teams

   UC3: Machine UI adaptation to individual user

   UC4: Machine-based adaptation

   UC5: Information entering and production monitoring

   UC6: Priority setting for measurements

B. Knowledge sharing

   UC7: Knowledge sharing

C. Training

   UC8: Learning while working

   UC9: Skill-based training

   UC10: Process-oriented training

D. Participatory design

   UC11: Re-configuring the assembly line with participatory design

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In order to maximize the outcome of the workshop the learning café approach was used. Participants were split into four groups and they visited stops where they discussed the use cases organized under the Factory2Fit topics. Each stop had a person who presented the theme and took notes on a flip chart. The stops were: (1) adaptation I, (2) adaptation II, (3) training and knowledge sharing, and (4) participatory design (Figure 2).

During the workshop, participants visited three stops. At the first stop they discussed why the proposed use cases were needed, ideas for solutions and expected impacts. At the next stops, they discussed similar themes, complementing other groups' results.

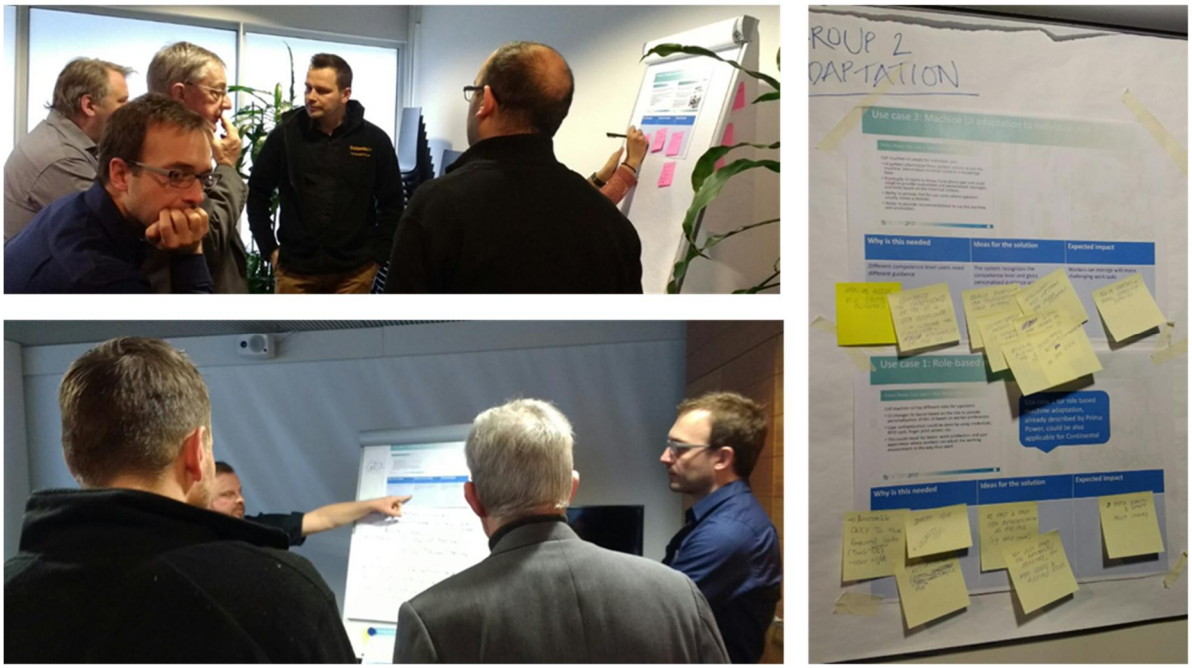

Figure 2: Group work during the workshop.

As a result three use cases were mainly discussed during the workshop, knowledge sharing (UC7), process oriented training (UC10) and re-configuring the assembly line with participatory design (UC11).

Participants agreed that the UC7, knowledge sharing, was relevant in different situations to create a more efficient and human workplace. Starting with the training of novice workers who requite to learn the work tasks and operations. It also supports recognizing critical phases and tasks. And it is crucial to solve situations where problems happens and there is no guidance available to solve them, the experience accumulated and its proper sharing provides a quick and efficient way to solve these situations. In order to enhance knowledge sharing solutions, participants suggested augmented reality (AR) systems that could make contextual guidance available during the actual tasks. Video analytics was recognized to be important if there is available a video database. Participants foresaw many possible impacts of knowledge sharing: workers can solve problems independently and get machines quickly back in operation; possibility to get feedback to design (e.g. suggestions to changes in design); using the data in planning the training (e.g. identifying challenging situations); real-time knowledge

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sharing with experts (remote assistance), and possibility to use knowledge sharing in different product life-cycle phases (commissioning, maintenance).

Participants recognized that the UC10, process oriented training, is important to be considered when training for a new production environment. Training times could shorten and tailored to each worker, experienced workers would not get bored in learning new things, important tasks can be remarked, and the ramp-up times would be shortened. As a solution to be used in this use case, participants suggested Factory2Fit project's Virtual Factory where workers could practice actual tasks and train problem solving. Workshop participants suggested that UC10 can be combined with UC7 as training overlaps with knowledge sharing. As expected impacts, participants raised the fact using the Virtual Factory process oriented training will allow to train workers event before the new production line is installed and thus would be ready to use it immediately after commissioning. Process oriented training would increase general awareness (including safety) how different production phases affect to another. Also with this concept, the participants saw a possibility to give feedback to developers and trainers.

The third discussed use case was UC11, Re-configuring the assembly line with participatory design. It raised the discussion of its focus: does it concentrate on design or re-design, and does it include design of machine or process. However, participants saw that PD is needed because it captures ideas for improvements. Workers have the experience and the know-how of the work which could improve the design. They acknowledged that bi-directional information flow is important because workers need to know why certain decisions are made. Participants thought that virtual factory, AR, gamification and social network tools could be used as a solution for this. Important impacts could be engagement, loyalty, better decisions and transparency in design decisions.

2.2 Workshop 2

The second workshop was focused only on the WP4 topics: participatory design, knowledge sharing and training. Participants were divided into three groups around the three industrial partners: Continental, Prima Power and UTRC-I (Figure 3). The participants stayed in the same group throughout the workshop. The purpose was to ideate one or more use cases for each of the WP4 topics. The aim was to discuss use cases in more practical level for example their goals, actions, actors and solutions to be used (e.g., virtual factory model, AR). In addition, the purpose was to set goals for developing demonstrations for the solutions and create working groups to achieve them.

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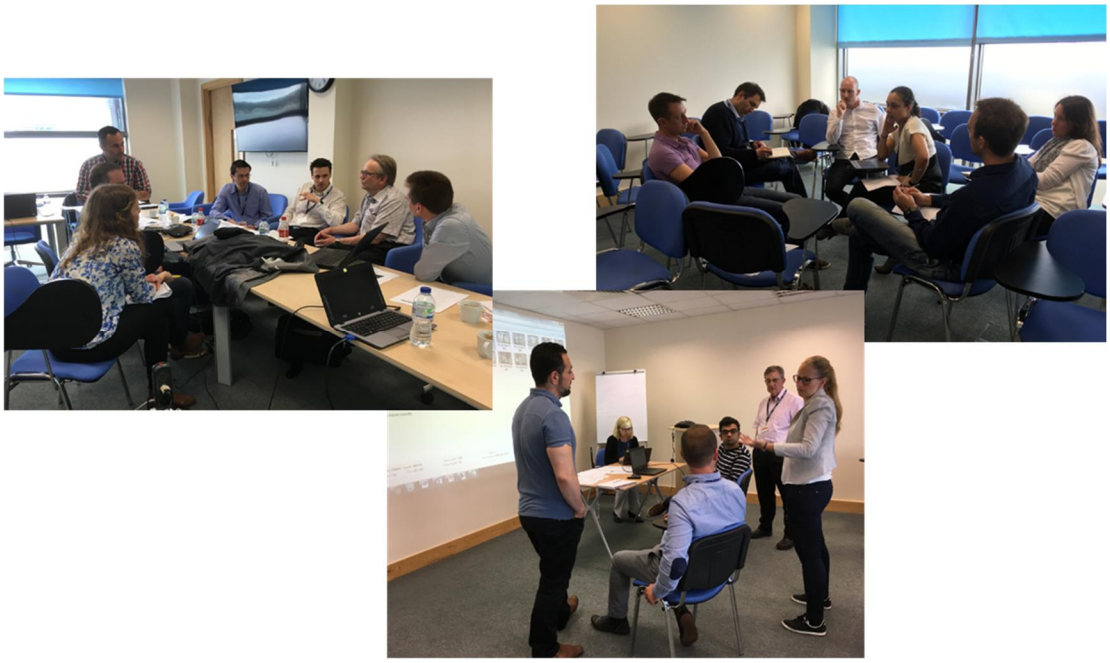

Figure 3: Discussion of within three industrial partner groups.

In the Continental group there were discussions regarding training and knowledge sharing. Three different use cases were identified: digitalization of work instructions for training, workers producing content for work instructions (knowledge sharing) and mandatory training content for beginners with a verification of acquired skills (training) (Table 3). Video-based technologies were seen as main enabling solutions to support training and knowledge sharing.

Table 3: Continental use cases.

	Use case	Description of use case	Enabling technologies/solutions
Continental	Training and knowledge sharing	Digitalization of work instructions (training)	Video clips, slides and/or text format provided in the intranet
		Workers producing content for work instructions (knowledge sharing).	Virtual factory could be used for making some of the videos
		Mandatory training content for beginners with a verification of the acquired skills (training). Suggestions of training content based on skill level and when was the last time worker performed the task; some of the content can be mandatory.	Worker profiling system to identify skill level

The Prima Power group discussed two topics: training and knowledge sharing (Table 4). In the training use case, it was proposed that virtual factory model would be used to train operators before the actual

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machine usage. In the knowledge sharing use case, Prima Power could use virtual factory model and AR solutions to support contextual information visualization.

Table 4: Prima Power use cases.

	Use case	Description of use case	Enabling technologies/solutions
Prima Power	Training	Preparation course for the training supports developing skills needed in the actual training (e-learning). Operators can be trained in realistic environment and with actual tasks as well as with actual problems well before the actual production line is installed.	Virtual factory model
	Knowledge sharing	The operators are provided with contextual information related to time, position on the manufacturing line, materials used and/or a customer order. The operators learn problem-solving in actual use. The tacit knowledge generated is gathered proactively and it is used to annotate the official guidance and documentation. Showing documentation, telemetrics etc. to the worker.	- Prima Power machines and systems - Add-on system interface on a tablet - Virtual factory model - Augmented reality solutions

UTRC-I group discussed a use case related to video-based training (Table 5). The purpose is to take a picture of the target component and use it when searching video instructions from the video library. Videos are recorded of the expert workers performing tasks. In addition, AR technologies could be used to identify automatically components.

Table 5: UTRC-I use case.

	Use case	Description of use case	Enabling technologies/solutions
UTRC-I	Video-based training	Take a picture of the target and search related videos. Videos are recorded of sub-assembly tasks when experts are working. Possibility to have spoken instructions of an expert. There could be two types of videos: training and at the work use. Augmented reality (HoloLens) could identify automatically the objects you are working with. In addition, AR could remark if about to make a mistake. Also for knowledge sharing and complementing with comments	Video analytics Augmented reality

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These two workshops (Workshop 1 and Workshop 2) guided the work for the definition of use cases in Factory2Fit project. The deliverable 1.3 *Adaptation Concepts* describes these use cases in more details.

2.3 Workshop 3

During this workshop, initial demonstrations of the WP4 concepts were shown. The goal was to show what has been developed so far and co-design the solutions further. Four different concepts were demonstrated: (1) on-site training: video-based learning system (UTRC-I), (2) off-site training: pre-training by using virtual factory platform (Prima Power), (3) knowledge sharing by using social media application and AR technologies (CERTH), and (4) collaborative/participatory evaluation of new technologies and levels of automation (TUC).

Learning café approach was used during the workshop. Participants were split into four groups and they visited demonstration stops. All groups had a possibility to visit three learning café stops, try out the systems and make comments (Figure 4). At each stop, one person demonstrated the solution and documented discussion and comments.

Figure 4: Four learning café stops: on-site training (top-left), participatory design (top-right), pre-training (bottom left) and AR technologies (bottom right).

Participants provided comments and feedback of the concepts as following:

On-site training system

- Industrial and research partners were impressed and agreed of the potential of the tool.

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- It was suggested to have a feedback mechanism in the tool such that when users exit the tool that mechanism can ask them to rate the tool in terms of usability and success on finding what they were looking for
- The possibility to use text in indexing training videos was requested because it is possible that taking pictures or using smartphone/tablet could be restricted.

Off-site training system, using the virtual factory platform

- General feedback for off-site training tool was positive
- Participants suggested that additional supportive material for training should be used to describe more necessary background information
- Virtual environment should be part of the course which is arranged to customers
- Topics of the training cases should be things that are causing more problems and could enhance understanding

Augmented reality tools - Microsoft HoloLens presentation

- Technical feedback
    - improvements to interface
    - voice commands should be more responsive
    - "placing" system could be more intuitive
- Additional functionalities
    - Training solutions (such as on-site training system)
- Concerns:
    - Safety issues need to be acknowledged because worker may lose focus on the real environment
    - Workers need training
    - High cost

Social interaction and co-operation tool (this was shown only for one group)

- Work schedule of a worker must be available in the social platform, so that the worker can check his/her personal schedule and forthcoming tasks.
- This requires that the worker should have a device (mobile phone, tablet, smart watch) where the information is provided

Collaborative/participatory evaluation of new technologies and levels of automation

- Virtual Factory Platform supports very well understanding of discussed processes and work places
- Modification and rearrangement of existing layouts as well as placing new components is quite simple
- Modeling and modification of work processes too complicated for workers to do. Therefore an experienced simulation software user is a mandatory.
- Providing fully functional layouts and models for PD workshops and knowledge sharing initially requires a big investment of time and might be challenging for factory-wide application
- Creating and modifying tasks is not intuitive

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These concepts are described in more detail in the deliverable 4.2 *Engaging participatory design, training and knowledge sharing solutions*.

2.4 Workshop 4

Workshop 4 was arranged to get feedback to the concepts from factory workers. The purpose was to study how workers see the concepts, what are the benefits and challenges, and how concepts should be developed further. Four concepts were discussed in the workshop: (1) *knowledge sharing and co-operation*, (2) *visualization of information with AR tools*, (3) *PD*, and (4) *on-site training* (Figure 5).

The *knowledge sharing and co-operation* concept can be used with smartphone or tablet, and it provides a social media based platform for instant messaging e.g. to ask advice from co-workers or to share hints with them. Videos and photos can be used in messaging. Searches can be made to former discussions to support problem-solving.

The concept *visualization of information with AR-tools* was demonstrated using Microsoft HoloLens. The goal of the concept is to provide context related information at the workplace. Information can be videos, messages from other co-workers etc. AR tools can also visualize different applications such as a gamification tool. The gamification tool supports knowledge sharing with gamification features (e.g., collecting points when sharing important information with co-workers).

The *participatory design (PD) concept* uses Virtual Factory platform to visualize designs for all stakeholders. It can be used for co-designing of workplaces and work tasks.

On-site training tool is providing support and possibility to learn work tasks on the factory floor. Workers can take photos of the parts to be assembled and then make a photo based search to find assembly guidance videos related to the part selected. The application can be used with a smartphone or a tablet.

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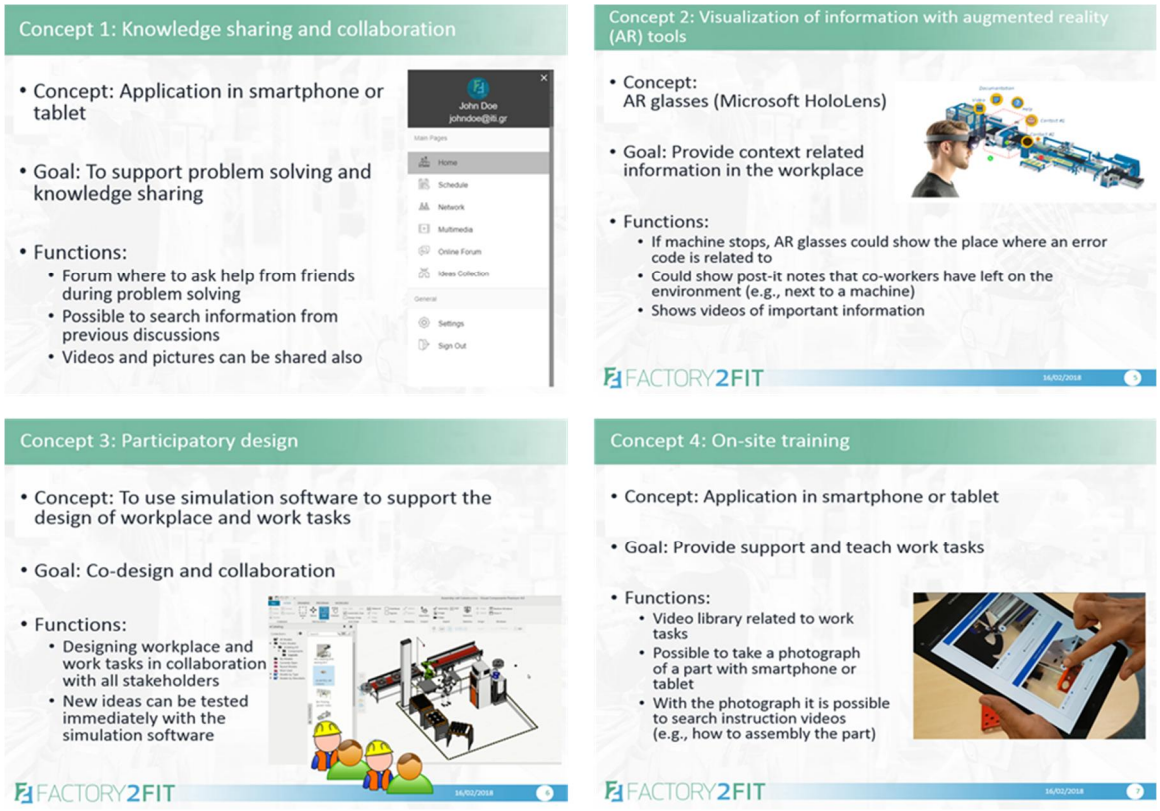

Figure 5: WP4 concepts: knowledge sharing and collaboration, visualization with augmented reality tools, participatory design and on-site training.

The workshop was arranged at the Prima Power factory and eight workers took part to the workshop (Figure 6). The participants were all male and their age range was 33-55 years (average 46 years). Three of them were factory workers and five higher-level employees. All participants were active computer and smartphone users and they all had some experience with navigators. Regarding smart glasses or head-mounted displays two had some experience, four knew the term and two had no knowledge of them. Two participants were active users of wearable technologies (e.g., smart watch), two had some experience, three only knew the term and one had no knowledge. Six knew the term of gesture-based control system (e.g., Kinetic) but two had no knowledge of it. With augmented reality technology, four knew the term and four did not have knowledge of it. With virtual reality technology, one had some experience of it, six knew the term and one had no knowledge.

The concepts were presented to the participants one by one. Concepts 1 and 2 were demonstrated for the participants, and videos were shown of concept 3 and 4. After each concept presentation, the participants first filled in a questionnaire. Then the concept was discussed in two groups: factory floor personnel (3 participants) and other stakeholders (5 participants). Benefits, challenges and improvements of the concepts were discussed in the group. The design and evaluation framework from the deliverable 1.5 *Design and evaluation framework and measuring tools* was used when planning the workshop and in designing the questionnaire to have a broad overview to work well-being topics.

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Figure 6: Demonstration of the augmented reality concept (HoloLens).

Based on the results, *social interaction and co-operation tool* was seen to be easy to use for finding information. Another identified benefit was that the information would be available in one place. The participants thought that the tool could make factory work more interesting and improve performance. As a challenge, participants mentioned that managing and moderating the data could be difficult. In addition, language could create a barrier for the use. Participants suggested that there could be a possibility to access also other information through this concept (e.g., instructions, project information). Main impact of this concept would be the efficient operations due to availability of the knowledge.

The participants saw that *the AR-tool* could be useful in training and design. Especially, novice workers could benefit from using it. With the AR glasses, both hands are free to do the work. The participants felt that pictures and videos are more illustrative than words. In addition, they thought that the tool would make factory work more interesting. However, the participants said that AR tools would probably not be used in a near future due to current AR device prices and the efforts that it will take to create interactive content. In addition, they were concerned of the acceptability of the AR tool among factory workers. They identified safety risks when using HoloLens on the factory floor because it narrows operators' field of view. The gamification component was not seen very useful. The participants suggested new usage ideas for the AR tool, for example the identification of parts and real-time information of the current status of the machine. Main impact of this concept would be efficient training, design and operation phases.

Participatory design concept was seen useful especially when designing the layout of the assembly line/station. The participants thought that the Virtual Factory tool would make it easy for all to participate, and it would support the recognition of design errors. The participants agreed that using the tool could improve the performance of the factory worker. In addition, using the tool could make the job of factory worker more enjoyable. However, they pointed out that the concept is not suitable

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for designing complex and changing tasks. The participants were also concerned if all required information is available when making design decisions. In addition, it is not easy to find consensus if there are many different opinions. They saw the use of PD concept useful but thought that it would be used only rarely and not as a part of the daily factory work. Main impact of this concept would be identification of tacit knowledge workers obtain.

On-site training tool idea was seen to be good. It was easy to use, practical and seemed to function well. The concept could be useful in assembly and with novice and subcontractor workers. The participants saw that the tool could make the job more enjoyable, improve performance and would be well accepted among factory workers. As a challenge, the participants mentioned that creating content could be laborious. In addition, the structure of the content can be difficult to form due to large number of parts and complex part hierarchies. The concept could be developed further by integrating it to other related data and information (e.g., part numbers, drawings). The participants suggested complementing the search with text that would narrow the search scope. Main impact of this concept would be access to easily understandable guidance.

From all four concepts the participants liked the on-site training tool and social interaction and co-operation tool the most. They think that the training tool is cheap, simple, easy to implement, easy to use and could be used daily. The co-operation tool was liked because it supports discussions and makes them visible. Therefore, it is useful when you need to ask help from your co-workers.

2.5 Workshop 5

To gain more feedback from actual workers the Workshop 4 was replicated in Continental's measurement lab on March 2018. Eight measurement lab workers (two females) participated to the workshop. Five of them were between 46-55 years, two under 25 years and one 56-65 years old. The translation and analysis of the data is on progress and the results will be reported on the updated deliverable on M30.

2.6 Workshop 6

On-site training tool presented on the Workshop 4 will be evaluated with factory workers in a Workshop 6 in the end of March 2018. The purpose is to study how workers see the on-site training tool, what are its benefits and challenges, and how it should be developed further. The results will be reported on the updated deliverable on M30.

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4 Discussion

Based on the results, co-design workshops have proven to be useful in the development of the WP4 solutions. Through the workshops it is possible to see the evolvement of solutions from the identification of industrial requirements to conceptualization phase and finally to solution development.

Main findings from the workshops, especially from the Workshop 4, were that participants' attitudes towards Factory2Fit concepts are positive. Especially, concepts "on-site training" and "knowledge sharing and co-operation" were seen very useful. The participants liked the concepts due to the ability to use them easily in every-day work. Therefore, concepts that can be used with smartphones and tablets are accepted to the use on the factory floor today. The possibility that all needed information would be used through one application was seen beneficial. It would be helpful that all discussions, photos and videos would be stored in one place and integrated with other information (e.g., part identification numbers, project information, drawings).

The AR-tool was seen potential because it leaves hands free but it raised many concerns regarding safety: it is difficult to fit to small places with large AR glasses on and AR glasses can diminished the visibility to an environment (e.g., forklift traffic). Another major concern was related to the management of the information: how the information is classified/grouped, who moderates the information, and how different software are integrated together to be able to share information between them. In addition, language issues may become as a barrier when sharing knowledge.

Main impacts of the WP4 concepts would compose from the availability of the information and knowledge. The knowledge can be shared between co-workers (different skill levels, novice vs. expert) and between product life-cycle phases (e.g., design, assembly, use). For example, by using PD approach workers could give feedback to designers, and by using AR-tools experts could remotely give guidance for novice workers. The access to knowledge would decrease the amount of errors and shorten the error recovery time. This would have positive impact on the efficiency and the quality of work. Training would decrease the time to learn for example when adopting new production line. Job satisfaction would advance due to support that WP4 concepts could provide if problems occur. These solutions could also affect as improved worker engagement, worker loyalty and transparency in decision-making (e.g., during the design).

As a next step, these concepts should be developed further to be able to use them in WP5 pilots. The usability of particular concepts should be tested with the users but main development work will focus on the integration of WP4 concepts with other Factory2Fit modules. In addition, the information management needs to be considered more thoroughly. The impact of these solutions will be evaluated and reported in the updated deliverable M30. In addition, data from the Workshops 4 and 5 will be analysed further with the help of a Design and evaluation framework presented in D1.5. These analyse results will be reported on updated deliverable on M30.

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5 Conclusions

This deliverable has reported the results of the workshops arranged during the task 4.5 Co-design with stakeholders. The purpose was to define, develop and evaluate WP4 solutions related to participatory design, knowledge sharing and training. Based on the results, participants' attitudes towards WP4 concepts are positive. Foreseen impact of the concepts, from the consortium point of view, was that easy access to knowledge could improve the efficiency of the production due to short recovery time from challenging situations. The workers foresaw that access to knowledge and training information would improve work satisfaction and performance of factory workers. The solutions seem to impact positively on empowering and engaging workers. The iterative development of the WP4 solutions will continue but focuses more on the needs of industrial pilots (WP5). Further evaluations of WP4 solutions will be reported in the updated deliverable M30.

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