Requirements for Scenarios and Prototypes

WEKIT D1.4

Requirements for Scenarios and Prototypes

Editor: Milos Kravcik

WEKIT
Wearable Experience for Knowledge Intensive Training
Project No 687669

Revision History

Version	Date	Contributor(s)	Modification
0.1	13.05.2016	Milos Kravcik	ToC
0.2	16.05.2016	Mikhail Fominykh, Veronika Kupriyanova	Review of TOC
0.3	17.06.2016	Kaj Helin, Timo Kuula	Requirements for Case 3
0.4	27.06.2016	Peter de Lange	Houses of Quality
0.5	27.06.2016	Roland Klemke	Next Steps
0.6	27.06.2016	Milos Kravcik	Missing parts
0.7	29.06.2016	Jazz Rasool, Carl H. Smith, Brigitta Zics	Medical case requirements
0.8	30.06.2016	Milos Kravcik	Incorporation of internal review remarks
1.0	30.06.2016	Cinzia Rubattino	Creation of final version

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WP 1 | D1.4

Editors:

Milos Kravcik (RWTH)

Authors:

Peter de Lange, Istvan Koren, Ralf Klamma (RWTH)
Kaj Helin, Timo Kuula (VTT)
Jazz Rasool, Carl H. Smith, Brigitta Zics (RAV)
Roland Klemke (OUNL)

Reviewers:

Puneet Sharma (UiT)
Carlo Vizzi (AL)
Cinzia Rubattino (GFT)

Deliverable number	D1.4
Dissemination level	Public
Version	1.0
Status	final
Date	30.06.2016
Due date	M7

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Executive summary

In WP1 the WEKIT consortium develops a framework for wearable experience, specifies a corresponding methodology for vocational training, creates suitable application scenarios, and derives requirements for the technological platform accordingly. The first findings are documented in the Deliverables 1.1-4. This deliverable (D1.4) is the first outcome of the WEKIT Task 1.4 *Requirements for Scenarios and Technological platform*, where the stakeholders can continuously collect, update, and negotiate requirements for Wearable Technology (WT) and Augmented Reality (AR) solutions, which should be developed in this project. The end-user requirements have been elicited through co-design activities and captured in *Requirements Bazaar*, a social requirements engineering toolkit that was initially developed by RWTH in the *ROLE* project and was awarded the best demo paper award at the *IEEE International Conference on Requirements Engineering* in 2013. Later on it was successfully used also in other projects, including *Learning Layers*. The *House of Quality (HoQ)* approach was adopted to offer a consulting tool for assessing technological options and comparing available tools for AR based workplace learning support. Here we present the current status of the collected requirements, which will inform our developments in the technical work packages WP2-WP5. This report will be later on updated in M21 and M36.

1. Introduction

As specified in our Description of Action (DoA), WP1 defines the framework and requirements to be used for all technical developments (WP2, WP3, WP4, WP5). Furthermore, the framework sets the foundation for piloting phases and their evaluation (WP6) and for exploring next steps (WP8). Looking at the details (also from DoA), WP1 links the scenarios and prototype requirements as follows, *paying special attention to the parts in italics*.

"All captured data [in scenarios] will be analyzed by a Learning Experience Model (LEM) and delivered for other users (trainees) through re-enactment by "wearing" the recorded experience. The delivered experience [provided by prototypes] will be augmented with the prior captured data (for example, superimposing the hands of the expert). In addition, biofeedback data... will be collected from both the expert and the trainees to determine the emotional state of the trainee, give hints during performance ... and use in post analysis. *The system design will include available state-of-the-art AR and WT hardware devices and components. However, the wearable experience framework will be developed considering the constant improvement of the technology.*"

WEKIT Deliverable 1.4 *Requirements for Scenarios and Prototypes* relates to Task 1.4 *Requirements for Scenarios and Technological platform*: Based on the Requirements Bazaar methodology and toolkit, requirements are continuously collected, updated, negotiated, and corrected among the stakeholders involved (lead participant RWTH, contributors: OBU, RAV, OUNL, VTT, CCA). The scope of D1.4 is as follows: This deliverable provides input scenarios (WP6) and prototypes (WP2), T1.4 (M6/M21/M36).

This deliverable gives an overview of the requirements for scenarios and prototypes collected in the first seven months of WEKIT by the project partners. This process started at the kick-off meeting in Milan and continued off-line on the *Requirements Bazaar*, which is a social requirements engineering platform developed for this purpose and successfully used in several major projects in the past. The technical partners have met later on in Oxford, in order to specify their technological affordances as well as limitations. To get feedback from more contributors (up to now mainly from the project consortium), the use cases from the Requirements Bazaar (https://requirements-bazaar.org/#!/projects/155) have been made public also via a special section on the WEKIT Community Portal (https://wekit-community.org/ideas/). In this way we involve end users, designers and developers from the beginning in our decision processes. All the collected input has been processed using our *House of Quality* instrument. Considering the relevance of the collected requirements, the project partners will design and develop the AR-based technological platform for knowledge-intensive vocational training. But as the scope, capabilities and influence of WEKIT Community grows and its new events take place, the requirements elicitation process will continue and in the future we plan to update this report.

In the following we first explain our methodology for large-scale social requirements engineering. Then the collected requirements for WEKIT scenarios and prototypes are presented. The main outcome is a list of requirements weighted according to user demands. Finally we outline our next steps and conclude this deliverable.

2. Methodology

Meeting the WEKIT challenges requires a sound methodological basis to develop the technological platform. The selected survey methodology relies on three activities, including requirements engineering based on the activities involving end-users; collecting and describing technologies that are available to support WEKIT scenarios and use cases; and employing an assessment instrument

that shall facilitate decision making by comparing products in terms of how well they support the elicited requirements. The requirements should play the role of a vehicle to transfer the framework pedagogical ideas into a clear set of technical requirements.

In order to document and compare the different technologies and to obtain a traceable approach to infrastructural decision making, the technology survey task was approached using the methodology (illustrated in Fig. 1) that relies on three activities:

1. *Technology Collection:* The objective of this activity was to collect technological features that are potentially relevant and related to WEKIT using a desk research approach. See Section 2.1.
2. *Requirements Engineering:* The objective of this activity was to elicit, consolidate, and prioritize user requirements from different end-user sources and design activities in WEKIT following an open development approach. The requirements are the main ingredient to building a technological platform that serves the WEKIT objectives, as described in the other two WP1 deliverables - *D1.1 User Industry Needs* and *D1.3 WEKIT Framework and Training Methodology*.
3. *Technology Assessment:* Based on the artifacts obtained in the requirements engineering and technology survey activities, House of Quality (HoQ) [1] was adopted as an instrument for obtaining and assessing technical requirements to be met by technology products using the collected technologies and the prioritized user requirements.

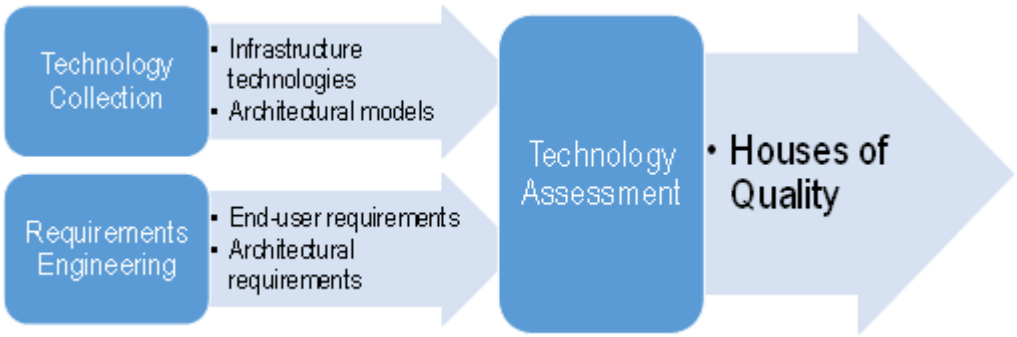

Figure 1. Technology Survey Activities and Outputs

To involve suitable stakeholders, a use case exercise was performed at the beginning of the project with the WEKIT pilot partners Lufttransport, ALTEC, and Ebit. Moreover, we collected input from the WEKIT Community of stakeholders by means of several activities and tools. The project partners were collecting ideas to help developers push the boundaries in what will be possible with the WEKIT.one technology platform - providing wearable experiences for knowledge intensive training. During the idea collection phase (leading up to a project report in May 2016 and a more extensive scenarios report in November 2016), the partners discuss these ideas - with respect to whether they are possible, whether they address significant challenges that are currently unsolved, and whether they bring out the best in what is technically feasible.

2.1. Technology Collection

The technological features (see Section 3.3) that may be relevant for WEKIT have been identified in Task 1.3, which deals with the research and development of the WEKIT Framework and Methodology, described in Deliverable 1.3.

2.2. Requirements Engineering

In parallel to the technology collection activity described in the previous section, there were several initiatives in the project to elicit user requirements with end-user involvement. Software architectures are built based on functional and non-functional requirements. In WEKIT, we elicited two sets of the user requirements.

Early in the project 15 main use cases have been specified by the consortium members (see Section 3.1). The requirements for them were elaborated during the technical meeting, which took place in May 2016 in Oxford. These use cases can be found also in the WEKIT Community Portal.

Other thoughts from the WEKIT Community (see Section 3.2) have been collected at the Kick-off Meeting in January 2016 in Milano, then at the AR Hackathon in April 2016 in Aachen, as well as during the JTEL Summer School in June 2016 in Tallinn.

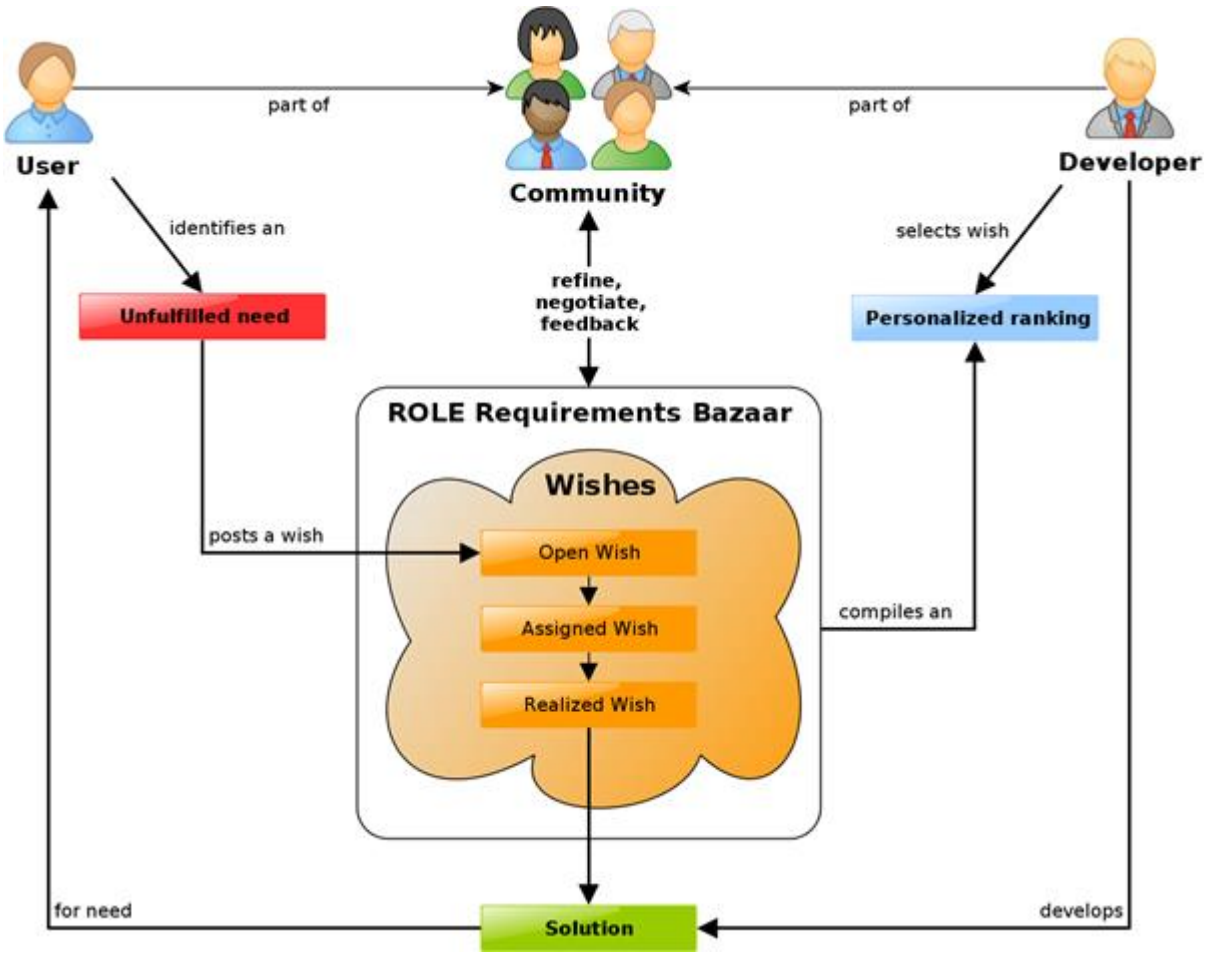

Figure 2. Schema of Requirements Bazaar

The functional requirements obtained were ingested into *Requirements Bazaar* (http://requirements-bazaar.org) [2] [3] [4], a tool developed by RWTH Aachen University in the context of the ROLE project. The Requirements Bazaar is a browser-based social software platform (see screenshot in Fig. 3) for *Social Requirements Engineering (SRE)* addressing the challenge of a feedback cycle between users and developers in a social networking manner. Stakeholders from diverse *Communities of Practice (CoPs)* are brought together with service providers (developers) into an open, traceable process of collaborative requirements elicitation, negotiation, prioritization and realization (Fig. 2). A vital communication between all stakeholders of an open source project is

essential in this regard [5] [6]. The Bazaar aims at supporting all stakeholders in reaching their particular goals with a common base: CoPs in expressing their particular needs and negotiating realizations in an intuitive, community-aware manner; service providers in prioritizing requirements realizations for maximized impact.

The Requirements Bazaar was used in the requirements engineering step for a collective voting process, in order to achieve a ranking of the elicited functional requirements, as an input for the quality function deployment (see Section 2.3). Partners were asked to express their opinion through casting a vote on the most important requirements. The vote consisted of a like on a certain requirement. The voting options available for each requirement were "Like", no action and "Dislike". Through this collective process, all the existing requirements were rated, enabling the prioritization of requirements. The ranking was constructed by sorting the requirements list according to the scores obtained after the voting procedure. A portion of the obtained prioritized list can be seen in Fig. 3. Moreover, partners were also encouraged to comment on the requirements, in order to allow further refinement of the available requirements descriptions.

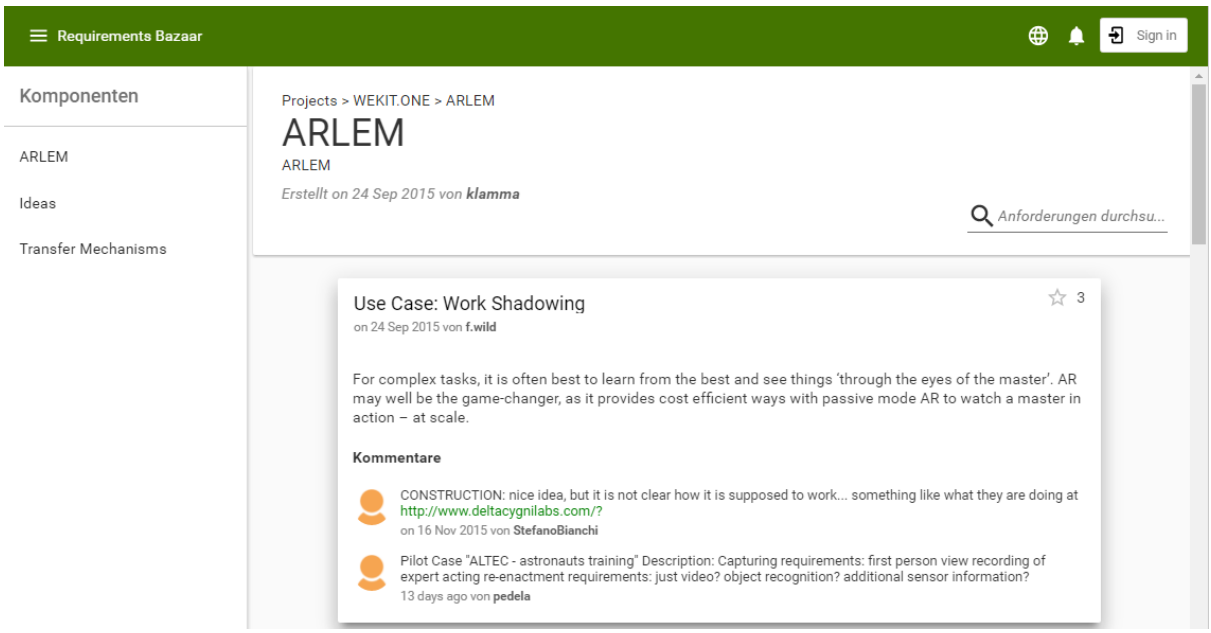

Figure 3. Screenshot of Requirements Bazaar

The resulting weighted list of requirements was end-user input to the House of Quality approach described in the next section.

2.3. Technology Assessment: House of Quality

We need to be able to make controlled technological decisions, which are informed by the actual needs of end-users. Therefore we chose to deploy a well-established methodology that will allow us to map technical features offed by new and existing components with end-user requirements in the context of use, which will typically be defined by one or more design teams. The general methodology we chose is called Quality Function Deployment (QFD) [7], and the particular instrument we adopted to map features and requirements is called House of Quality (HoQ) [1].

QFD is a methodology that aims to drive product design by customer requirements. Its instantiation is HoQ, a product development technique that follows the principles of QFD and has been originated in Japan in 1972 long before in the 1980s it was adopted by large U.S. firms such as Ford, Xerox and AT&T for their product development activities. The instrument allows identifying those parameters

of a technology that are especially important taking into consideration the user requirements. In the case of the WEKIT technological platform, we use the HoQ to get a weighted list of functional requirements based on the respective demands and needs of the design team scenarios.

HoQ establishes a matrix of requirements coming from both the customer and the engineers designing the product. Using this approach, user requirements can be transformed into a weighted list of engineering characteristics that need to be met by the candidate products. It also supports the assessment of existing technologies in terms of how well they perform when meeting the user requirements.

Fig. 4 shows an exemplary scheme of each HoQ. On the left side, customer requirements (e.g. indoor navigation, experience recording, assembly guide) are entered one-per-row together with a weight calculated in user surveys. On the right existing products are rated by the end users (usually on a 0-5 scale, where 0 means "not possible with this product" and 5 "totally fulfills this requirement"), thus resulting in a market analysis. Engineering characteristics are entered on a column basis together with an improvement direction. At the bottom end of each column, improvement targets and the difficulty of reaching this target is recorded.

Figure 4. The Scheme of a House of Quality

In the next step, all engineering attributes are related with each other in the roof of the HoQ. Hereby positive or negative correlations in two graduations each are entered. That is, a plus is entered if on improvement of attribute A also attribute B is improved, and a minus is entered, if improvement of attribute A degrades attribute B at the same time.

The most important part of the HoQ methodology that also leads to the weighted engineering characteristics as output is setting the customer requirements in relation with the latter attributes. Hereby relations are rated in a numerical system with the higher number being higher related. A system is adopted that assigns strong relationships the value '9', medium relationships a '3' and weak

relationships a '1'. Stronger relationships also lead to a stronger influence in the weight calculation at the bottom.

Another benefit of using HoQ is that it enables traceability of product attributes as for every weighted engineering characteristic the original user requirement can be traced in the matrix. In further steps, the output of one matrix may also be cascaded as input of a new one thus enabling traceability. For software products, further matrices may be applicable in terms of software modules within a broader infrastructure.

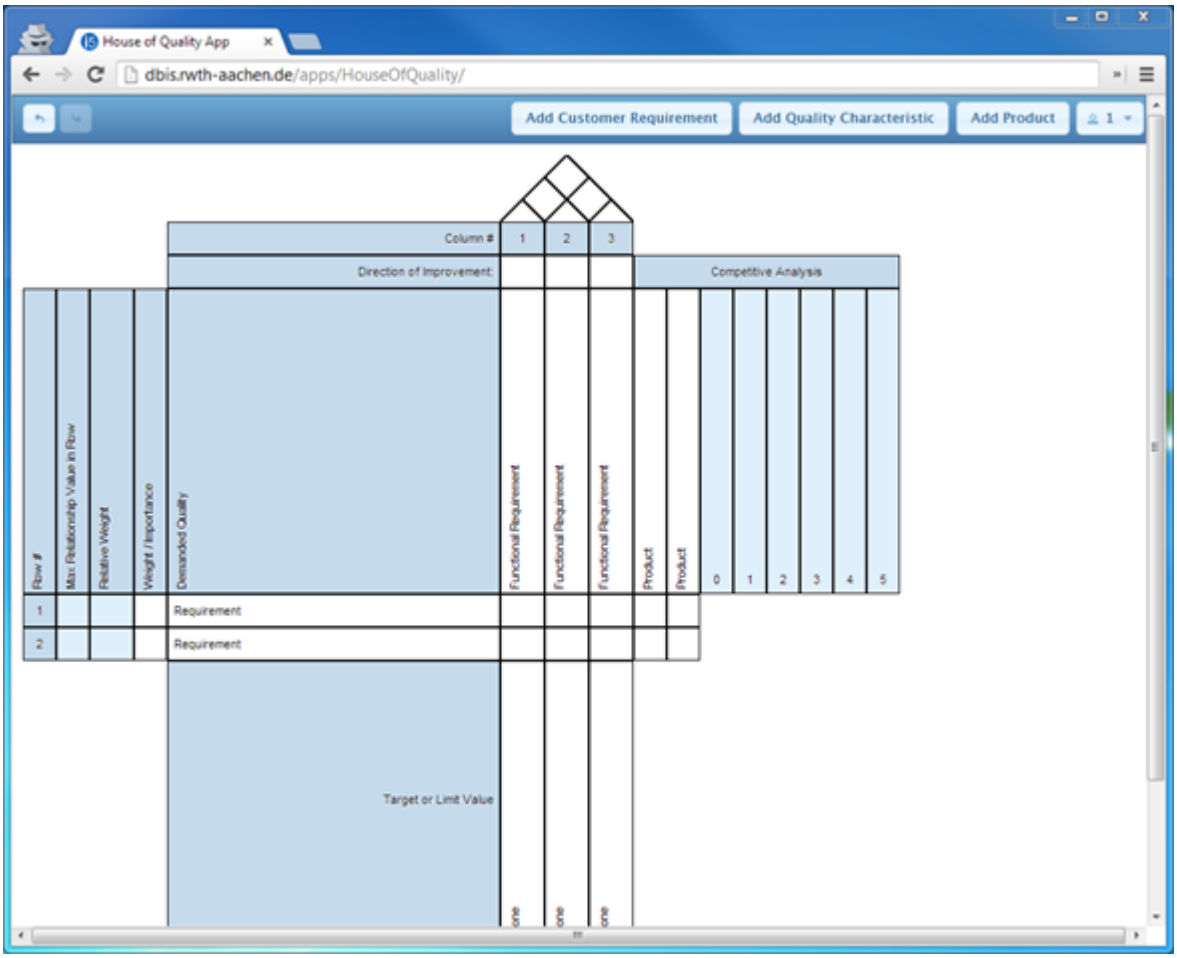

Figure 5. The Collaborative House of Quality Web Application

In the end, all the weights of customer requirements are charged against the product attributes according to their relationship factor. The output on the bottom is a list of weights for each product attribute that can then be incorporated in the product design. As described above, the results may be integrated into another HoQ matrix.

In WEKIT, two preliminary HoQs were built up to month 6 to test-drive the methodology. The user requirements elicited and then weighted through the voting process in Scenarios - Use Cases (component ARLEM) and the WEKIT Community Input (component Ideas) were used as input for the left part of the HoQ. The technical features from the WEKIT Framework (component Transfer Mechanisms) were instantiated for the technical part on the top of each HoQ. We found that the requirements were partially too general for enabling decision making using the Quality Function Deployment method.

To promote and explain the HoQ methodology and foster participation of the design teams, we used a collaborative Web application earlier developed in the Learning Layers project that is based on Google Drive and allows multiple persons to jointly work on a HoQ, as shown in Fig. 5. The tool is also available on the Google Chrome Store [8].

3. Requirements for Prototypes

In this section we present the requirements collected for the WEKIT prototypes. We collect them in our Requirements Bazaar in the WEKIT.ONE project [9]. There three different components have been created:

1. ARLEM: Input from WP6 Scenarios [10]
2. Ideas: Input from WP7 WEKIT Community (Community thoughts - unabridged and unfiltered) together with Technology affordances from WP2-5 [11]
3. Transfer Mechanisms: Input from T1.3 WEKIT Framework (Transfer mechanisms as identified in Framework and Methodology) [12]

The collected requirements are processed as outlined in Fig. 6. The objective is to process the different types of input from various resources, in order to inform WP2 (technology platform) and WP6 (pilots) about the most important requirements for them. These two cooperate closely, as WP2 develops prototypes that will be tested in WP6. WP2 also integrates the technology provided by WP3-5 and complements the methodological framework from WP1 with a modular architecture.

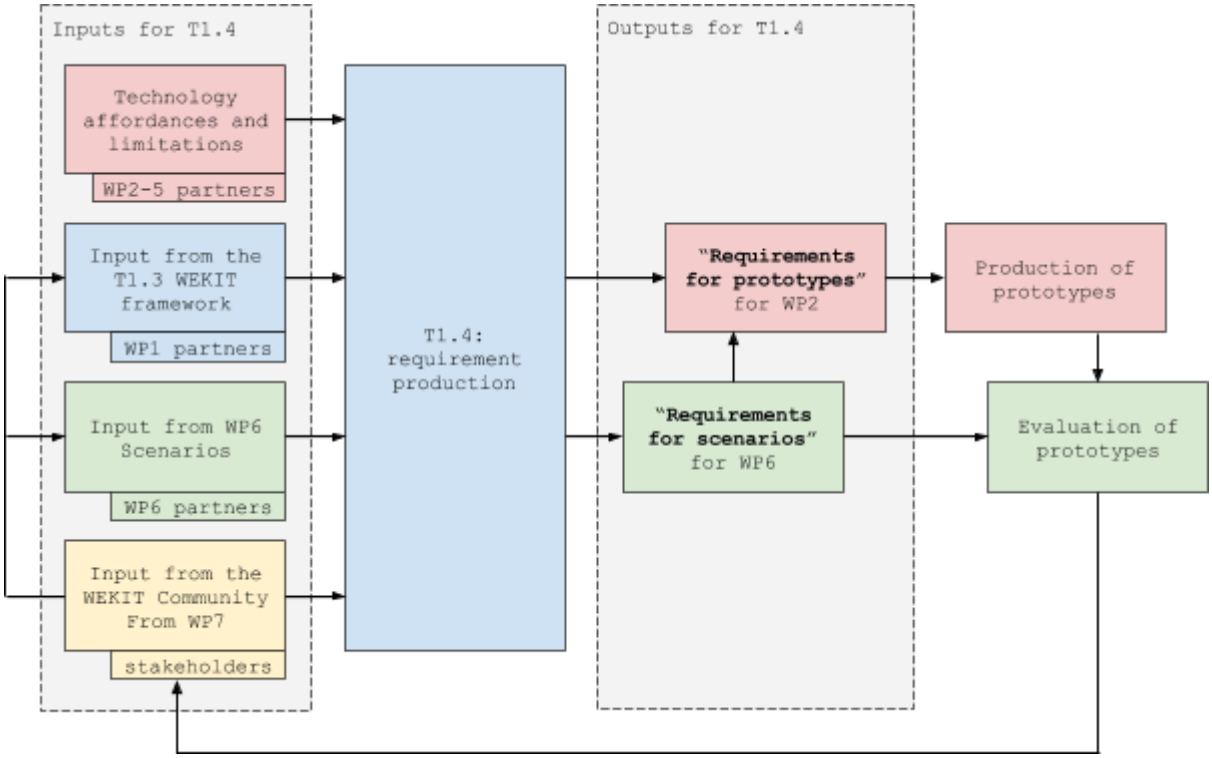

Figure 6. Processing Requirements in Task 1.4

3.1. Use Cases

This is our list of collected use cases:

1 Use Case: Wet rehearsal Simulation in the real context: Rehearsal on the actual workplace and actual objects, newbie training, before they can do the real thing. Recording Standard Operating Procedures (for an audit) is such an example.

2 Use Case: Assessment Experience recording helps collect evidence of task performance ˜by the bookâ (and can be replayed to others). Such recordings on-push-of-button or at-hot-spots can be later brought up again to support career development: evidence helps assess, where training is required and proves whether staff is able to do the job within the specs required. Service technicians.

3 Use Case: Experience Recording Active AR in authoring mode is used in a show and tell way to extract key steps from existing documentation. User generated content can be used to convert existing technical documentation into augmented documentation.

4 Use Case: Health Learning Imaging, wearable sensors, and biometrics enable the enlightened patient to better control well-being, using direct biofeedback to understand and modify own behavior. For example, visualizing x-ray or MRI data in situ on the body, using an interactive mirror, helps people understand conditions in a better way. Physical therapy for rehabilitation, patient self-help, Yoga Trainer, etc. all work the same principles: understand better what is happening inside of you and use it to your advantage.

5 Use Case: Indoor Navigation With the help of indoor positioning, navigation in confined space becomes possible, where GPS is not available. This is a very fundamental use case, required for many other learning activities, where locations matter not only when you need to find a particular room (e.g., patient in hospital).

6 Use Case: Maintenance Not only mechanics are able to do repairs and maintenance operations. Many products today are not repaired, but disposed, when faults occur, as the cost of professional labour (and travel of engineers or postage) often is more expensive than producing a new unit. Changing the motor on a washing machine, replacing a chain, gearbox, or brakes on a bike, changing the electronic window levers on a car, supporting installation of a complex wire harness: the amount of AR-supported DIY opportunities is sheer endless.

7 Use Case: Quality Inspection Assessment comes in many disguises, quality inspection for high precision jobs being one of them. In manufacturing, for example, product assurance is key.

8 Use Case: Remote Tutoring Not only professionals, but also home users with a certain level of manual dexterity would benefit a lot from live tutoring and guidance, receiving remote support in situ and on the job. Stuck with changing the motor in your washing machine? Call the service agency on the smart glasses to receive live hands-on guidance.

9 Use case: Resume Service Human Resources would so love to visualize experience of candidates, enhancing the resume. Check compliance of workers is an example (for compliance assessment).

10 Use Case: Retail Training Bring up product information on the go, mediate knowledge to the customer.

11 Use Case: Safety and Wellbeing Helping to implement new regulations with respect to safety and worker wellbeing by providing hazard warnings and safety instruction in place in the real environment. For example, safe handling of x-ray machine to protect the patient and operator. Could also make use of projection-based AR.

12 Use Case: Smart Lighting Providing guidelines through projection-based AR.

13 Use Case: Spatial Coordination Guide the user to focus on task (maybe using eye tracking).

14 Use Case: Tangible Learning Objects Using 3D-printing and Internet-of-Things hardware, we can breathe new life into objects, using their tangible features as interfaces to software functionality and logic. A relay box simulator is an example of this.

15 Use Case: Work Shadowing For complex tasks, it is often best to learn from the best and see things through the eyes of the master. AR may well be the game-changer, as it provides cost efficient ways with passive mode AR to watch a master in action at scale.

3.2. Ideas

The following thoughts have been collected at the live events (Kick-off Meeting, AR Hackathon, JTEL Summer School) as well as via the WEKIT tools (Community Portal, Requirements Bazaar):

16 4D real time organ reconstruction Healthcare professionals like cardiologists or radiologists benefit in diagnosis and in explaining diagnoses to patients from visualisation of clinical data. 4D reconstruction merges data from ultrasound, ECG, and CT scans and overlays live sensor data to illustrate conditions in real time.

17 Live non-conformance report creation As soon as an assembly operation goes wrong, technicians can quickly create a non-conformance report using the camera of smart glasses, voice commands for hands-free navigation, and speech input for adding notes. Related past cases can be brought up upon request, helping to learn from previous errors, e.g. helping to spot patterns.

18 Record an expert user as basis of training By recording an expert user working on a task, we have a record of the actions and techniques used to complete the activity. This information can then be used as the basis for creating training material. Using a combination of technologies to capture the expert user, clips of video can be used to illustrate training material as well as to simply understand what was being done. Whole scene video cameras, audio recording of the person describing what they are doing, and head mounted cameras would all combine to capture a lot of information. If a known VIP user does the experience capture, a trainee can claim to have been trained by the best. As a side benefit, gaze tracking could be used to determine where user-interface and annotations could be placed without hindering a trainee.

19 Capture astronauts' behaviours By capturing astronauts' behaviours (i.e. for emergency procedures training), it would be possible to learn from mistakes or incorrect actions in order to improve the performance of the procedure. This could be done using video recording and eventually using sensors to measure stress and others health parameters (heartbeat, etc.). This could be also applied to doctors.

20 Automating checking for maintenance workers All checking procedures in maintenance can be significantly improved by capturing all steps. Such automation will save time and ensure that all procedural steps were done and reported, especially for shift handover.

21 Capturing completion of each step in procedures Long procedural check (such as in aviation) can have an mechanism for insuring that each step has been done. The maintenance workers usually do not remember if they have done a particular step right after they have completed the procedure. Technology can be used to (a) give the worker an additional assuring factor that all the steps were done and (b) create a digital record of the particular procedure execution, so that it can be referred to later.

22 Aircraft engine rigging Aircraft engine rigging involves adjusting various components associated with control system in order to get a smooth performance of the aircraft during flight. It requires strict conformance to procedures described in the manufacturer maintenance manuals and service instructions. For this, technology can be used to provide better training, sharing of experience, and capturing best practices. Such a solution can save time and reduce the associated costs. Furthermore, during this task the technicians use safety glasses, this means that the technological solution should accommodate for that.

23 Helicopter track and balance Track and balance is the process of reducing vibrations in the body of aircraft, which are caused by helicopter's rotor system. Technology can be used to provide better instructional input on the maintenance data. Having this solution would reduce time and improve the quality of maintenance procedures. In this procedure, the technicians usually wear safety headset/earmuffs, so the proposed solution should conform to these safety requirements.

24 Aircraft maintenance training and assessment There is strong need of an automated solution to provide better training (by using easier instructional input methods) and assessment of aircraft technicians. This would, first, reduce the total number of supervision hours. Second, increase the number of training sessions. Third, it can also be used for standardization of training and assessment procedures.

25 Pre-flight inspection Pre-flight inspection is used to determine if the aircraft is in airworthy condition. In order to conduct a pre-flight inspection, a lot of paperwork and reference information is gathered and studied before actually proceeding to the aircraft to conduct the inspection. To this end, an automated solution can reduce the time and improve the quality of inspection.

26 Tutor supervision Lecturers like to see how students are doing with their weekly exercises, so they can focus helping those who are stuck. Smart glass technology could provide information about students when seeing them (or even lead towards them, display waiting time). To avoid privacy problems, maybe students should actively submit data, asking for help, when they are struggling?

27 Healthy living Guide patients in the supermarket by providing live nutritional information on products, overlaying data on the actual packages. Help in selecting the right components of a healthy meal (and avoid that bad stuff) - so we live longer and with a better quality of live.

28 Customer-driven DIY repairs Lot of equipment gets thrown away, because the repair costs (due to high labour costs) are more expensive than purchasing a new product. AR on phone, ipad, or smart glass could provide the required competence to repair things at home (or in office). The app would have to monitor my actions and inform me where I make mistakes. Anything is possible: from fixing the dishwasher to home plumbing guidance. Where I get stuck, I can call a remote expert (for pay, but cheaper than if the expert travels to my home). Famous example of this in a different medium is the Haynes Manual: see e.g. https://haynes.co.uk/catalog/car-manuals

29 Assembly guide New machinery arrives and it needs to be assembled. The app guides me step by step.

30 Surgery practice Medical surgeons can practice performing surgery - virtually. 3D reconstruction of organs (and conditions) help to understand how to manoeuvre the body and how organs interact.

31 Installation and construction assistant Smart glasses help to install and assemble equipment safely and correctly. For outdoor use, this means that the devices in use have to work in all weather conditions.

32 Personal rehabilitation trainer Rehabilitation only works when exercises are performed correctly. This reha trainer would give direct feedback when things are done right (and when not). This helps to increase utility of the training sessions, requiring automated measurement of quality of exercise.

33 Magic Mirror for Sports and Reha Scan body posture and use additional sensors to gain real time as well as post workout feedback to improve performance - in a visual way. For example, body posture can be scanned with devices such as MS Kinect or Intel RealSense to then overlay a skeleton or stickman model over the mirror video image - live and in real time. For specific body movements in workout, the ideal posture can be visually highlighted and deviation can be marked up (red shades), where detected - guiding people better how to do movements with precision. Or, as another example, gas exchange measurement can reveal whether you are burning fat or carbohydrates - and this can be displayed on the magic mirror by augmenting your body video image (or its background) with burning flames ("you're on fire with this workout"). Trans-magnetic stimulation can be used, measuring via leg and head specific muscle excitation - creating a feedback loop to stop you from going to far, working out in the wrong zone. Lactate levels provide feedback on training intensity. Load of body sensor data exist in professional sports coaching and professional rehabilitation (e.g. stroke patients) - sensor fusion and holistic visual body augmentation could provide an engaging way to increase performance.

34 hackWall - A collaborative augmented graffiti wall Users can scan QR codes placed on walls. Then, a collaborative paint canvas appears "on the wall" and is editable by everyone and synchronized in real time. User may choose between different drawing devices and colours or attach images, links and videos to the wall. Both "traditional" mobile devices and smart glasses should be compatible, since it will be implemented using Web Standards. Cyclops, "The goal is to build an AR game, where you shoot projectiles with your AR glasses. You target a virtual castle, with enemies shooting back at you. Your goal is to destroy enemies by directly shooting them or use the advantage of explosives hidden in the castle"

35 boxingAR AR game where users use beacons and sensors such as the Leap Motion or Myo armband to find and defeat virtual monsters as fast as possible. Enemy attacks have to be dodged or blocked, otherwise you suffer a time penalty.

36 ExplorAr The main focus of this idea is the collaboration of people that have a certain goal in learning. With a leap motion detector and virtual glasses people can browse between multiple objects that they can inspect. The selected object from the catalogue is projected on the table in 3d and via hand detection can be rotated, transformed and exploded into parts that can be examined separately from the group members. From separating in components and examining them individually the group members can change and try different options for the building they are examining. The application can be used mainly in architecture and civil engineering!

37 Assessment Experience-recording helps collect evidence of task performance by the book (and can be replayed to others). Such recordings on-push-of-a-button or at-hot-spots can be reused later, e.g. as proof of competence, for career development: evidence helps assess where training is required and whether staff can do the job within the specs required. Example: certifying Service Technicians.

38 Experience Recording Active AR in authoring mode is used in a ˜show and tell way to extract key steps from existing documentation. User-generated content can be used to convert existing technical documentation into augmented documentation.

39 Health learning and health awareness Combining imaging, wearable sensors, and biometrics to sensitise patients and health professionals to AR-based ways to better understand and communicate the status and anticipated evolution of particular medical conditions, for example, visualizing x-ray

or MRI data in situ on the body, using an interactive mirror, helps people understand conditions in a better way. This might help to influence wellbeing, using direct biofeedback to understand and modify own behaviour. Likewise for physical therapy for rehabilitation, patient self-help, Yoga Trainer, etc. all involve the same principles: understand better what is happening inside of you and use it to your advantage.

40 Indoor navigation With the help of indoor positioning, AR-based training to navigate in confined space becomes a powerful way to overcome lack of aids such as GPS. This is a very fundamental use case, required for many other learning activities, where locations matter â€“ not only when you need to find a particular room (e.g., patient in hospital).

41 Procedural guidance - space cargo module As an astronaut I want to repair the fan inside the cargo module. SO THAT: I get the ventilation working. TOOLS: Manual tools. AR tools for assisting and supporting the work. WHY? To get relevant support while repairing the fan. CONCERNS: If using AR tools makes the work more difficult or uncomfortable.

42 Procedural guidance - space cargo module (2) As a TRAINER I want to make training more effective and motivating for the astronaut. SO THAT the time needed for ground training reduces. TOOLS: AR visualization, authoring tool, VR environment, real mock-up. WHY? The time needed for ground training reduces and the astronaut can get personalised training while travelling. It's cost-effective and the astronaut doesn't have to spend too much time in ground training (motivation and well-being aspect). CONCERNS: It's too expensive to implement the system, the technology is not mature enough (usability, reliability etc. issues). The astronauts do not accept the system. There are not enough resources to maintain the system.

43 Procedural guidance - space cargo module (3) As a DEVELOPER I want to create novel and useful AR systems for training. SO THAT I can support astronauts in their work and provide tools for trainer. TOOLS: Unity, energy drinks, requirements (tech., human factors), learning content, Arduino. WHY? I want to learn how to utilise and develop new technologies (AR). CONCERNS: The technology is not mature enough, too many usability issues, compatibility issues with other software/hardware, the technology is developing too rapidly (today's stuff is old tomorrow).

44 Training support for radiologist/cardiologist AS a RADIOLOGIST/CARDIOLOGIST Practitioners and Medical Student I need to have support during my training phase in image based reporting being driven in comparison with 3D body organ model as well with use case found and compared in radiology education digital library. TOOLS: I imagine that using VR techniques, I am guided in the real case image processing analysis and report being projected over my scene the following: a) The 3D body organ model that I'm reporting; b) A relationship with similar use case that it could be found in the radiology education digital library on the same pathology as well. WHY: To get fast and proper information that help me during learning phase with advanced and automated procedure. CONCERN: Not really on the technology

45 Training support for radiologist/cardiologist (2) AS a RADIOLOGIST/CARDIOLOGIST Practitioners and Medical Student I need to have support during my training phase in image based reporting having a personalized learning experience. I need to have a guided procedure over imposed on a real scene that both help me in learning and using the proper tool of the reporting application as well compared with my standard protocol used. TOOLS: Using VR techniques, I am guided in the real case image processing analysis with a VR training expert guiding me in selecting the proper tools and protocol looking at the image based on pathology, acquisition techniques and so on. WHY: to get fast and proper information that help me during learning phase with advanced and automated procedure. CONCERN: Not really on the technology

46 Image comprehension for patient AS a Patient When the physician and GP provides me with a CD and an image reporting study I would like to be able to view at the images and report, being guided in the comprehension of the 3D reconstruction and structured reporting that has been applied. TOOLS: I imagine that using VR techniques, I am guided looking at my structured report being projected over my scene the following also: a) a comparison model with not affected organ showing the "process" to my pathology; b) The way in which the VR therapy may help projecting the evolution expected on my image study (that means the next image study I will expect as a result of the therapy). WHY: To be more engaged and empowered as a patient in understanding an image structured report as well in understanding the way the therapy help and what should I expect.

47 user feedback for developer AS a developer of image reporting application during my design phase of a touch screen GUI interface, I need to get feedback on the way the user interact with my application when compared with expected correct use. TOOLS: Having sensor and/or device that collect and get information on the way the user "interact" with my application. WHY: In order to produce an application GUI that could be more effective.

3.3. Transfer Mechanisms

Deliverable 1.3 specifies the WEKIT Framework and Methodology and based on it the technical features have been identified. Below, we provide their descriptions.

Remote symmetrical tele-assistance

Attributes: Expert and novice share each other's perspective view which enables expert to train the novice live

Requirements for recording: Shared display (or only expert sharing novice view) which enables expert to analyse the novice viewpoint

Requirements for replay/re-enactment: Tracking of the expert hand gestures and use voice

Virtual/Tangible Manipulation

Attributes: Possibility to manipulate and practice on virtually simulated objects with real life hand movements

Requirements for recording: Hand movement tracker, accelerometer

Requirements for replay/re-enactment: Hand movement tracker, accelerometer

Haptic Hints

Attributes: Feedback based on the physical movement of the arms or body

Requirements for recording: Expert accelerometer data on actions performed by myo gesture control armband (Thalmic Labs)

Requirements for replay/re-enactment: vibrotactile bracelets for hinting the type of current movement required

Virtual Post its

Attributes: Possibility to create and destroy reminder and marks that can be shared with others and for future reference

Requirements for recording: Possibility to tag an object or event

Requirements for replay/re-enactment: Possibility to see post it notes from other users or check own post-its from previous time frame

Mobile control

Attributes: Mobile support of some actions that would otherwise need to leave the workspace

Requirements for recording: Digital embodiment of the controls that change values in real time

Requirements for replay/re-enactment: Identification of variables that need to be controlled from another space AR/WT assumption; Overlaid virtual control buttons

In Situ Real Time Feedback

Attributes: Recognition of steps and suggesting steps

Requirements for recording: Recognition of steps and decisions

Requirements for replay/re-enactment: Recognition of steps and decisions

Case Identification

Attributes: display and identification general faults or mistakes by observing case studies and displaying images or information relevant to the case

Requirements for recording: Cases of common hard to identify error Experts on the field

Requirements for replay/re-enactment: Modelled expertise and inductive reasoning Possibility to reflect with the system's feedback

Directed focus

Attributes: Methodologies to direct the focus of the technician or reduce distraction

Requirements for recording: Data of experts eye movement at that individual step and expert inferring of the system for just in time assistance object of importance recognition

Requirements for replay/re-enactment: Blurring of irrelevant areas, highlighting the important object, followed by alternating between relevant-only (blurred) images and real-world images

Self-awareness of physical state

Attributes: display of fatigue precipitation (fatigue level, vigilance level), time on task, & other information for self-assessment & distraction analysis

Requirements for recording: Calculation of fatigue based on other attributes record of recommended distraction and fatigue level

Requirements for replay/re-enactment: display and feedback or warning of the enactor if the benchmark is breached

Contextualisation

Attributes: display of contextual information about: co-workers, location, process

Requirements for recording: contextual information should be part of the record and requires a metadata-model to record contextual data

Requirements for replay/re-enactment: contextual information of recorded context and contextual information of current context need to be clearly distinguishable

Object enrichment

Attributes: display of recognized objects with additional information

Requirements for recording: object recognition features enabled modelling of additional information for recognized objects

Requirements for replay/re-enactment: objects recognized during novice task execution need to be enriched in a consistent way via interaction elements that are automatically displayed to switch object recognition on/off or to interact with specific elements

Think Aloud Protocol

Attributes: replay of a recorded task is enriched with audio comments of the expert performing the task; audio comments can be added during original recording or added at a later stage

Requirements for recording: audio recording during recording phase video editing to add/correct audio track later

Requirements for replay/re-enactment: audio play (headset / speakers) audio controls noise reduction for audio quality

Zoom

Attributes: replay of a recorded task execution with higher zoom factor

Requirements for recording: camera with high resolution needs to be explicitly enabled in recording phase to trigger high resolution recording

Requirements for replay/re-enactment: video display and video interaction (change zoom factor, replay, auto-repeat) when zoom feature available, interaction elements are automatically displayed

Slow motion

Attributes: replay of a recorded task execution at lower speed

Requirements for recording: camera with high frame-rate to have enough level of detail for slower replay needs to be explicitly enabled in recording phase to trigger high speed camera

Requirements for replay/re-enactment: video display and video interaction (change speed, replay, auto-repeat) when slow motion feature available, interaction elements are automatically displayed

4. Requirements for Scenarios

WEKIT deals with three different cases - Aeronautics, Engineering, and Space. In this section we describe requirements for two individual scenarios – the second and the third. These will have to be further elaborated and entered in the Requirements Bazaar for further processing.

4.1. Engineering (Medical) Case

Pedagogical requirements

Key goal in training: Reviewing medical imagery in a seamless and integrated way for broad and detailed effective decision making in diagnosis, prognosis and patient communication.

Figure 7. WEKIT Medical Use Case

Doctors need to focus their efforts on effective decision-making after reviewing variety of medical imagery combined with patient data (medical history, use of medication, etc.)

This clinical health use case is designed to provide doctors in training as well as regular doctors with the opportunity to receive data about the patient and the patient's condition in the most effective and efficient way.

Using Augmented Reality this application displays a variety of medical imagery combined with patient data (medical history, use of medication, etc.) as an overlay on a patient manikin. Doctors can perceive this imagery, as it is superimposed on the body and they are able to switch between methods of scans and data easily. CT scans, Ultrasound, Echocardiography, MRI, 3D imagery, and other medical

imagery can be represented at any given time. The AR interface can provide seamless navigation between various data sets, allowing doctors to focus their efforts on effective decision-making. For training we are proposing an effective method that allows a large amount of imagery to be combined and presented within a patient information-rich context.

- From a Doctor/Practitioner perspective, complex cases can demand examination of many different kinds of medical imagery and data.
- From the Trainer/Hospital perspective, there are many points of data gathering and presentation. The practitioner may need to use several systems that are not interoperable in order to be set up the prerequisites for initiating analysis.

Generic learning goals: Supporting and enabling broad and detailed effective decision making in Medical workflows requires considerations such as:

- The level of mental load incurred can make it challenging for the practitioner to make effective decisions around diagnosis, prognosis or for patient communication.
- Use of several imagery and data systems often is a competitive and time consuming activity with several practitioners possibly needing access simultaneously. This can lead to delays if equipment is already being used by other practitioners. The delays could have potential side effects related to patient conditions not being addressed in a timely manner.
- Lack of a single imaging system means that doctors must use several media to communicate medical results effectively to patients. A lack of effectiveness may lead to confused or reduced patient compliance around engaging with follow up treatment plans.

Specific requirements for learning systems: When training people to understand medical imagery, it is difficult to identify one particular method for training.

- What is known is that looking at a large amount of image use cases (imagery which describes and explains the medical condition) can enhance our understanding and ability to identify that medical condition.
- A flexible training environment is proposed, where trainees can engage with and edit information linked to patient data including various types of medical imagery.

Training goals and requirements suggested by a Medical trainer:

- A flexible interface would allow the trainee/doctor at a particular section/points of the image to highlight supplementary information and add voice recordings, transcripts as speech bubbles, or any other visual cues, visible only when selected.
- Similar medical cases would be linked and can be found via keywords. For the inexperienced learner, all the actions should be explained with limited telemetric data.
- The training could use existing archive data, which can be constantly expanded and updated. Since with archival data, confirmed diagnosis will be available, the training can use that to assess whether the doctor in training diagnoses correctly and identifies conditions.
- Reflection and validated assessment tools can be provided in electronic form to provide independent measures of diagnostic performance.

Scenario requirements (scripts)

- The patient manikin can be enriched in the above ways with additional imagery data, providing vision into the body, where otherwise imagination has to replace sensory information.
- The manikin can simulate patient reaction, where appropriate, creating a more lifelike experience for the training. In comparison to special purpose hardware simulators, such a

manikin with AR software overlay should be cheaper than the very pricy hardware manikins.

- An additional option to this training method could be live expert guidance. This would allow trainees to receive additional information and add their own notes to the existing content. This could include visual and haptic guides for conducting specific procedures (in the style of, for an ultrasound, 'start measuring the head-size here and measure up to there, where the head ends').
- Eye tracking technology could be an optional sensor source for the training: expert eye-movement could be represented on the display or even, if possible, differences between trainee fixation points and saccades and the expert eye-movement could be highlighted (this could be post analysis or in real time during training action).
- Users: Trainees, long-term vision that doctors would use this too.

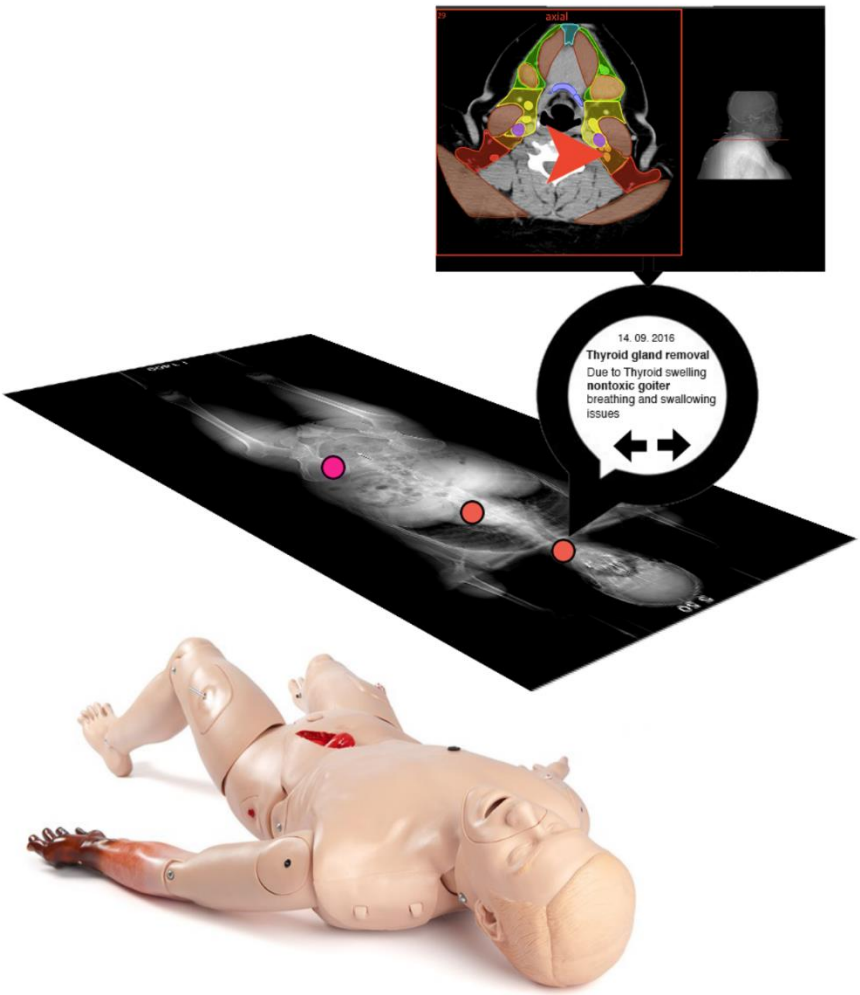

Figure 8. WEKIT Medical Use Case – Concept Illustration

4.2. Space Case

Pedagogical requirements

Key goal in training: Changing the learning method.

Decreasing the ground training time is a key target: The aim is to shorten the ground training and teach only the most important and necessary things before the space mission. The trainers have to prioritize and additional training must to be created for learning objectives that are not prioritized. The goal is to shift from long and comprehensive ground training periods to situational, self-directed autonomous learning in space.

- From astronaut viewpoint, it's not possible to be completely ready and prepared for 3 years mission; they have to learn things during the mission with on-site learning systems.
- From trainer / company viewpoint, the systems become more and more complex. It's not feasible to organize very extensive training of everything before the mission.

Generic learning goals: Supporting and enabling autonomous decision making in space.

- The astronauts cannot be followed in real time during long missions. The time lag between ground control and spaceship communication can be 6-20 minutes (one direction). The astronauts have to make decisions without guidance from the ground.
- The AR system should be able to follow changes and adapt: it should be able to record situations and present new information next time.

Increasing task performance speed in space: Doing things quickly, well and safely.

- Trainer / company viewpoint: Time is a critical and expensive resource in space. Tools that reduce task performance time and increase cost-effectiveness are needed.
- Trainee (astronaut) viewpoint: Reducing time especially in emergency and life-threatening situations would be important. Increasing task performance speed in such situations improves safety.
- Note: If AR is not technologically mature, it might decrease the speed.

Specific requirements for learning systems: Recognizing the learner's level of expertise and type of personality (e.g. learning styles & preferences). Both of these are affecting the learning situation and need, and a successful solution should recognise these elements.

- For the inexperienced learner, all the actions should be explained with limited telemetric data.
- For the expert, more telemetric data should be available (not too much visualization), and lower level simple actions and step-by-step instructions should be hidden (but access provided).
- Providing briefing and orientation (i.e. overall picture of the task) before the actual performance is important.

Training goals and requirements suggested by an Astronaut trainer:

- The astronaut understanding of the activity performed. (S)he should be more engaged in the task.
- The possibility to perform activities not previously trained when necessary.
- The possibility to operate at different knowledge levels, i.e. when repeating well known sequences the system should not slow down the operator or distract with unnecessary information.
- The possibility to correct or modify the instructions in case of inconsistencies with the stored material and to add notes or corrections.

Scenario requirements (scripts)

- System should be able to show telemetric and other non-visible data for astronaut.

- System should be able to simulate zero-gravity movements of assembly or disassembly parts.
- Authorization of the AR content should be done in realistic environment e.g. Virtual Environment or real mock-up.
- System should be able to record experienced persons/trainers workflow and should be able to distribute training scenario in several places with low network connectivity.
- System should be able to connect existing data (e.g. maintenance reports) and show them as request.

5. Resulting Houses of Quality

After collecting requirements and feedback to them in the Requirements Bazaar, we transferred them to Houses of Quality. By taking from the Requirements Bazaar the transfer mechanisms we described in Section 3.1 as "Quality Characteristics", we defined two Houses of Quality for both the "Ideas" component of the Requirements Bazaar as well as for the "ARLEM" component. The resulting HoQ can be found in the Annex 1 and 2. Using this formal method enables characterizing both the relationship of requirements to transfer mechanisms as well as transfer mechanisms to each other.

For the relationship between the quality characteristics, we identified only positive relationships to each other, meaning that improving / working on one mechanism also improves several others. While in some cases this is the result of one described quality characteristics being a special case of another, as it is for example with "Virtual Post-Its" and "Object-Enrichment", others really influence each other positively, like for example zooming can improve directed focus.

Probably the most influential quality characteristics for the successful realization of requirements is the "mobile control", which also symbolizes the importance of wearability of AR devices. Other important quality characteristics the framework needs in order to realize collected requirements are "In Situ Real Time Feedback" that allows for direct feedback to the user and object enrichment in general, one of the key features of augmented reality. The HoQ analysis also showed the importance of earlier definition of transfer mechanisms, since we identified for each of them several related requirements that are to be successfully implemented.

6. Next Steps

The key results from House of Quality for our further work are:

- The importance of wearability of AR devices is emphasized by the highly important "mobile control" quality characteristics.
- AR feature is represented by "In Situ Real Time Feedback".
- It is also important to define early the technical features (transfer mechanisms).

The requirements elicited so far and reported here will now be used as input to the first round of technical implementations in the technical work packages WP2-WP6.

- WP2 (Wearables-Enhanced Learning Technology Platform) builds on general platform relevant requirements related to learner experience modelling, interoperability, and modularity.
- WP3 (Wearable Experience Capturing and Analytics) takes requirements elicited for capturing, recording, editing expertise as input for the design and implementation of

capturing components, including selection of sensor frameworks, wearable platforms, and sensor integration components.

- WP4 (Augmented Reality Learning and Experience Re-enactment) relies on requirements elicited for re-enactment for the design and implementation of components helping novices during training and exercise phases, including visualization, information adaptation, learning, and analysis.
- WP5 (Workplace Integration and Human Aspects) takes requirements into account in defining the WEKIT design methodology for wearables as well as the corresponding visualizations and wearable design solutions.
- Also, requirements elicited will inform the industrial learning scenarios (WP6), which relate the requirements to the three pilot cases (Aeronautics, Engineering, Space) and which design the respective knowledge intensive training scenarios correspondingly.

As the current version of the deliverable D1.4 is only the first of three subsequent versions, feedback from the application of the requirements to the other work packages is also gathered and fed back into the updated versions of D1.3 and D1.4. We plan to keep internal versions of D1.3 and D1.4 updated regularly as internal project working documents and deliver them to the official delivery dates (M21, M36). This way, we keep the formal delivery dates, while maintaining a living document internally, which better reflects the agile development process applied in WEKIT.

Outputs of WP1, especially D1.3 (Framework) and D1.4 (Requirements) will also be used for dissemination. These practical outputs contribute to WEKIT's vision of applicable results distributed through WEKIT's community channels: while the framework and methodology aim to inform trainers, educators, and other application oriented stakeholders, the requirements rather target technical implementers such as hardware and software developers.

As a first result of these activities, we performed different workshops related to WEKIT framework, methodology, and requirements at this year's JTEL Summer School in Estonia. We presented WEKIT, the WEKIT framework and methodology and the requirements approach using Requirements Bazaar to summer school participants. Participants of the JTEL summer school comprise PhD students and professionals in the TEL sector. About 25 people participated in the WEKIT workshops, contributing to the application of the WEKIT approach to sample use cases and scenarios.

7. Conclusion

This deliverable provides the first collection of requirements for WEKIT scenarios and prototypes. They were elicited at several live events (Kick-off Meeting, AR Hackathon, JTEL Summer School) as well as through our tools (WEKIT Community Portal and Requirements Bazaar). Afterwards the members of the project consortium as well as of the WEKIT Community could rate them and comment on them.

The WEKIT partners collected three different sets of requirements - for use cases, community ideas, and technical features based on the WEKIT Framework. Then in two Houses of Quality we compared the technical features once with the use cases and once with the community ideas. As the outcomes of these comparisons are based on a rather limited amount of data, we must take into account this limitation when interpreting our results. We have identified only positive relationships between quality characteristics. The importance of wearability of AR devices is emphasized by the highly important "mobile control" quality characteristics. Another key AR feature is represented by "In Situ Real Time Feedback". Another finding is that it is also important to define early the technical features (transfer mechanisms).

The next versions of this deliverable are planned for M21 and M36, but we assume more iterations will be needed, in order to refine and elaborate the current set further and to acquire even more valuable input for WEKIT developers early enough. It requires time to get more stakeholders involved and get them engaged in contributing, discussing and rating the requirements. We believe the next community activities, especially the first WEKIT Community Event *Requirements Bazaar Kick-off* will help us to address a lot of new stakeholders and to acquire their input on relevant requirements.

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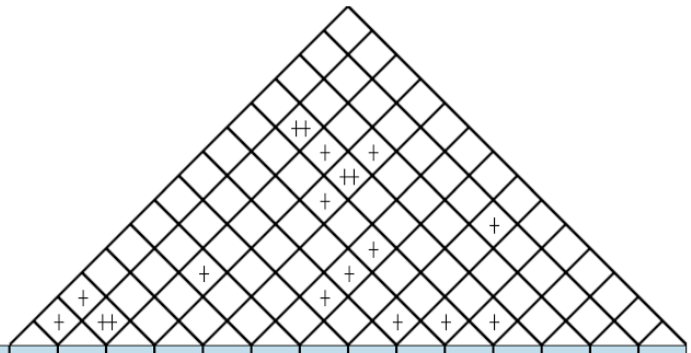
Appendix A: House of Quality with Use Cases

A larger version of the image can be found at:

https://wekit-community.org/wp-content/uploads/2016/06/House-of-Quality-App-Arlem.png

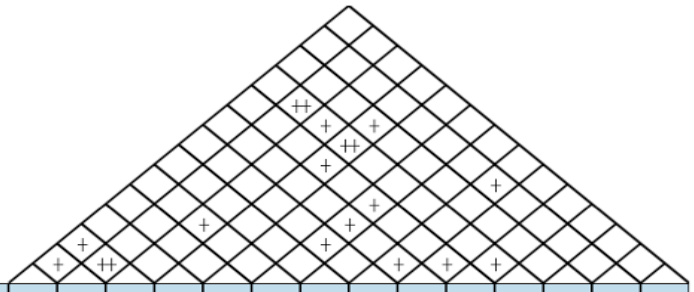


Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Demanded Quality	Remote symmetrical tele-assistance	Virtual/Tangible Manipulation	Haptic Hints	Virtual Post its	Mobile control	In Situ Real Time Feedback	Case Identification	Directed focus	Self awareness of physical state	Contextualisation	Object enrichment	Think Aloud Protocol	Zoom	Slow motion
				Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14
				Direction of Improvement:														
1	9			Use Case: Work Shadowing	O	▲						▲	▲		Θ			
2	9			Use Case: Tangible Learning Obects		Θ	O											
3	9			Use Case: Spatial Coordination	▲						▲	Θ					O	▲
4	3			Use Case: Smart Lighting											O			
5	3			Use Case: Safety and Wellbeing			O	▲		▲		▲			▲			
6	3			Use Case: Retail Training				▲				▲			O			
7	3			Use case: Resumé Service										O				
8	9			Use Case: Remote Tutoring	Θ				▲	▲	O							
9	1			Use Case: Quality Inspection		▲		▲			▲							
10	3			Use Case: Maintenance	▲	▲	▲	▲	▲		▲			▲	O		▲	▲
11	3			Use Case: Indoor Navigation					O	▲		▲	O	▲	▲			
12	3			Use Case: Health Learning	▲					▲			O					
13	3			Use Case: Experience Recording	▲		▲	O			▲	O		O	▲	O		
14	1			Use Case: Assessment										▲				
15	3			Use Case: Wet rehearsal	▲	O	▲		O					▲				
				Target or Limit Value	none	none	none	none	none	none	none	none	none	none	none	none	none	none
				Difficulty														
				Max Relationship Value in Column	9	9	3	3	3	1	3	9	3	3	9	3	3	1
				Weight / Importance														
				Relative Weight														

Appendix B: House of Quality with Ideas

A larger version of the image can be found at:

https://wekit-community.org/wp-content/uploads/2016/06/House-of-Quality-App-Ideas.png



Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Demanded Quality	Remote symmetrical tele-assistance	Virtual/Tangible Manipulation	Haptic Hints	Virtual Post its	Mobile control	In Situ Real Time Feedback	Case Identification	Directed focus	Self awareness of physical state	Contextualisation	Object enrichment	Think Aloud Protocol	Zoom	Slow motion
				Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14
				Direction of Improvement:														
1	3			user feedback for developer	▲			▲		○	○			○				
2	9			Image comprehension for patient							▲			▲	○		⊖	
3	9			Training support for radiologist/cardiologist (1+2)		⊖	○				○	▲	○		⊖	▲	⊖	
4	9			Procedural guidance - space cargo module					▲		○			⊖	○			
5	9			Procedural guidance - space cargo module (2)					▲		○			⊖	○			
6	9			Procedural guidance - space cargo module (3)					▲		○			⊖	○			
7	9			Indoor navigation			▲	⊖	○	▲		▲	⊖	○	▲			
8	9			Health learning and health awareness					○	▲	⊖		⊖	▲	⊖	○		
9	9			Experience Recording				○			▲		▲			⊖		
10				Assessment														
11	9			ExplorAr					⊖	⊖			○	▲	⊖			
12	9			boxingAR		○	⊖		⊖	⊖			⊖					
13	9			Cyclops					⊖	⊖								
14	9			hackWall - A collaborative augmented graffity wall					⊖	○			▲		⊖			
15	3			Magic Mirror for Sports and Reha							▲		○	▲			▲	
16	9			Personal rehabilitation trainer		⊖			▲	▲	▲		▲			▲		
17	9			Installation and construction assistant	○			○		▲	○	⊖		▲	⊖	▲	○	▲
18	9			Surgery practice	○				○	○	▲	○		▲	▲	▲	⊖	⊖
19	9			Assembly guide	○			⊖	▲	▲		▲			○		⊖	▲
20	9			Customer-driven DIY repairs				⊖	▲	▲		▲			○		⊖	▲
21	3			Healthy living				○	▲	○	▲		▲	○	▲	○		
22	9			Tutor supervision						⊖		○		○	▲	○		
23	3			Pre-flight inspection				▲				○			○		▲	
24	3			Aircraft maintenance training and assessment	○		○	▲				○			○		○	
25	3			Helicopter track and balance			▲		▲	▲			○					▲
26	3			Aircraft engine rigging			○		▲			▲						
27				Capturing completion of each step in procedures														
28	1			Automating checking for maintenance workers			▲	▲		▲								
29	3			Capture astronauts behaviours										▲		▲	▲	○
30				Record an expert user as basis of training														
31				Live non-conformance report creation														
32	3			4D real time organ reconstruction			▲				▲	▲			▲		○	
				Target or Limit Value	none	none	none	none	none	none	none	none	none	none	none	none	none	none
				Difficulty														
				Max Relationship Value in Column	3	9	9	9	9	9	9	9	9	9	9	9	9	9
				Weight / Importance														
				Relative Weight														

WEKIT

Wearable Experience for Knowledge Intensive Training
Project No 687669

WEKIT project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 687669. http://wekit.eu/