D1.5 WEKIT Framework & Training Methodology

The WEKIT Framework
Revision History

<table>
<thead>
<tr>
<th>Version</th>
<th>Date</th>
<th>Contributor(s)</th>
<th>Modification</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>25.07.2017</td>
<td>Bibeg Hang Limbu</td>
<td>Initial content drafted</td>
</tr>
<tr>
<td>0.2</td>
<td>28.07.2017</td>
<td>Bibeg Hang Limbu, Roland Klemke</td>
<td>Addressed the internal reviewer's comments. Major updates in sections operationalization example and reflection. Conclusion adjusted. Auditing performed to check for grammatical errors and overall clarity of the document.</td>
</tr>
</tbody>
</table>

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WEKIT Framework and Training Methodology

WP 1.3 | D1.5

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Deliverable number D1.5
Dissemination level Public
Version 1.0
Status final
Date 25.07.2017
Due date 31.07.2017
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Executive summary

The document reports on the status of the WEKIT framework. Building up on the methodologies described in D1.3, it outlines the work done and progress made so far in the Task 1.3. The WEKIT framework was drafted to guide and support the development and implementation of the project. It aims to support the transition of the trainers from the traditional training platform to the WEKIT approach.

The framework leverages on the vast knowledge and experience an expert possess. The framework aims to make the experts knowledge and experience available to the trainees by capturing the expert performance. The framework was built by performing an extensive literature review, expert interviews and through active participation of the WEKIT community and stakeholders. Experts that closely collaborated in the WEKIT project were from three completely different domains namely, Aeronautics engineering, Medical Imaging and Astronaut training. An overarching goal of the framework was to be domain independent and abstract, such that it does not rely heavily on domain related expertise.

The framework is built by units termed as Transfer mechanisms which are individual learning design methods that exploit expert performance with the help of Augmented reality and Wearable technology. These Transfer mechanisms allow various forms of training to be adapted to the WEKIT approach. The Transfer mechanisms also support components of the Four component instructional design for ensuring optimal learning using the WEKIT methodology. Four component instructional design model defines learning of complex task in a didactic approach where the expert plays a critical role. The framework supplements the model by technology enhanced learning methods that rely on expert performance.

The document also reports on current findings and future endeavours that WP1 will take to improve the framework and the project itself.
1. **WEKIT Abbreviations**

WP  Work Package

AR  Augmented Reality

WT  Wearable Technology
2. WEKIT Industry Learning Methodology

The WEKIT industrial learning methodology aims to utilize the valuable experience and knowledge that the expert possesses. Shortage of experts for training as resources limits the development of expertise in the trainees. The WEKIT methodology intends to make the experience and knowledge of the expert accessible and available to the trainees. The WEKIT industrial learning methodology consists of three major phases: capturing expert performance, re-enacting expert performance by trainees, and reflection. In addition, before the capturing phase, a preparation phase is required to ensure that essential aspects of the expert performance are identified for capturing. The Capture phase ensures that the expert records all the relevant information needed for the trainee to perform the task. The re-enactment enables the trainee to learn from the recorded performance while the reflection phase allows the expert and trainee to reflect on the trainee’s performance by observation or/and from the data collected.

**Preparation Phase:**
- Break down complex task to subtask (see Section 4C/ID)
- Identify properties of subtask (see Section Task type)
- Select Transfer mechanisms (see Section Transfer mechanisms)

**Capture Phase:**
- Choose required functionalities in the recorder based on the selected Transfer mechanisms
- Create learning contents using the recorder while demonstrating the subtask.
- Capture expert performance in units as subtask

**Reenactment Phase:**
- Enactment of the expert performance is conducted in the same/similar physical space as it was captured.
- Project expert created content into the relevant time and physical space
- Provided feedback by comparing expert performance model with trainee model

**Reflection Phase:**
- Automated reflection based on performance analysis
- Expert intervention to foster deliberate practice

*Figure 1. Phases of WEKIT industry learning methodology*
3. Goals of the WEKIT framework

This framework guides the development and deployment of AR & WT platform for industrial training. It defines efficient and effective learning methodologies based on an extensive literature review in addition to other forms of information collection such as interview with experts, questionnaires, community participation via Requirements Bazaar (see D1.4) and trial studies (WP6) which were also extensively used. The framework is flexible to adapt to different domains of training. The emphasis of the framework is on making the experts knowledge and performance accessible to large numbers of trainees in an effective manner. The identified goals of the framework are as follows.

Capture of Expert Performance: One of the objective of the framework is to define expert performance and the process of capturing it. The framework should provide a set of guidelines that will dictate the optimal procedure to capture expert performance. In order to accomplish this,

- Key indicators of expert performance were identified by reviewing literatures (see Section Operationalization).
- *Transfer mechanisms* (TM) were defined as instructional design methods that leverage on the captured performance of an expert for training purposes.
- The WEKIT recorder hosts a pool of functionalities that allow recording of expert performance that is fed into the re-enactment phase.

Re-enactment of expert performance: TMs which are units of the framework, also define re-enactment of expert performance within the framework. Each TM has been extracted from an earlier study in the literature which were mostly in educational contexts. In addition, the framework facilitates the Four component Instructional Design (4C/ID) by bridging AR and WT with traditional 4C/ID based training. Thus,

- The framework defines how the captured expert performance is to be used for optimal learning for supporting 4C/ID.
- The WEKIT player implements functionalities that supports re-enactment as defined by the TM.

Requirement generation: The framework produces concrete requirements to guide the development of the learning platform. Requirements for capturing and re-enactment of expert performance are described within the descriptions of TMs (see Section Transfer Mechanism). The framework significantly contributes towards generating other requirements such as sensor selection and use case requirements.

Evaluation of learning platform: In addition to guiding the development of the WEKIT platform, the framework also guides the evaluation of the platform. It outlines clear requirements and performance indicators that will allow evaluation of applications built upon the framework. It also monitors the adherence of the platform to the framework which was evaluated in the first WEKIT trials (see D6.1, D6.2 and D6.3). Further trials will consider learning outcomes as well.
4. **WEKIT framework**

4.1. **Expert Performance**

Expertise may be defined as the knowledge and skills behind an expert’s performance. However, attaining expertise is a difficult endeavour with claims that it may take up to 10 years of practice to be an expert (Gladwell, 2008). Ericsson, Prietula, & Cokely, (2007) emphasize importance of experts as mentors for supporting deliberate practice, thus, eventually supporting expertise development. However, experts tend to underestimate how difficult a task can be for the trainee (Hinds, 1999). Moreover, experts are often unaware of all the knowledge behind their superior performance (Patterson, Pierce, Bell, & Klein, 2010). Therefore, while experts are indispensable to expertise development in a trainee, learning from them is difficult. Moreover, limited access to the experts for the trainee hinders their development even further. To mitigate these problems, the WEKIT framework aims to capture expert performance, making it accessible to many trainees to support their deliberate practice.

Ericsson, Charness, Feltovich, & Hoffman (2006) claimed that practice should be aimed at improvement of a particular skill by reflecting on performance and collecting new experience in order for it to be deliberate. Deliberate practice relies on the one-to-one settings with the expert where an expert continuously provides guidance and feedback to the trainee (Benedict Carey, 2014). However, in addition to the difficulty in learning from the expert, one to one settings are rare with the shortage of experts. Moreover, deliberate practice is difficult to maintain and perform for the trainee alone (Rikers, Gereven, & Schmidt, 2004). By capturing expert performance as a resource to train trainees, the WEKIT framework supports deliberate practice by emulating an expert based guidance and feedback. However, there is a high amount of cognitive load associated with deliberate practice on the trainee as well (Rikers et al., 2004). The Four Component Instructional Design (4C/ID) model with its roots on cognitive load theory can be viewed as a potential solution for monitoring the cognitive load of the trainee.

Sarfo & Elen (2007) reported positively that the 4C/ID model promoted the development of expertise which was based on their assessment of the technology enhanced learning (TEL) environments developed with 4C/ID specifications. This claim is further backed by Neelen & Kirschner (2016), in their study where they found that the 4C/ID model supports deliberate practice which is essential for expertise development. In addition, the potential of sensors to personalize training in authentic contexts (Bacca et al., 2014) and the potential of AR to support trainee in real time, both facilitate deliberate practice in a trainee. Therefore, WEKIT framework builds upon 4C/ID by facilitating the model with AR and WT based instructions in order to support expertise development in a trainee.

4.2. **Four Component Instructional Design**

The 4C/ID model (Figure 2) is a non-linear and systematic processing model for designing a complex learning environment. It is a holistic approach that decomposes the complex task into their simplest and smallest elements such that can be easily transferred to the trainee through a combination of these elements (Van Merriënboer, Clark, & Croock, 2002). The basic assumption of the 4C/ID model is that all complex learning can be represented in combination of four components described by the model (Van Merriënboer & Kester, 2014), namely: 1. Learning task 2. Supportive information 3. Procedural information, and 4. Part task practice. The WEKIT framework supplements each of these components with TMs. The TMs enable instructional designers and trainers to implement AR and WT based training. At the same time, support for expertise development can be implemented by ensuring that all the components of 4C/ID are evident in the AR and WT supported training.
Learning Task:

Learning tasks are authentic, whole task experiences that are provided to the trainee in order to promote schema construction for nonrecurrent aspects of the task. For example, construction of schema by the trainee can be facilitated by observation or imitation of the expert. The learning task which are subtask broken from the whole complex task, are administered in an increasing complexity and its dependency on other learning task. Each learning task is scaffolded to reduce the support and guidance when the trainee attains higher form of expertise. In Figure 2, all the TMs that actually allow trainees to perform the task by imitating or observing the expert performance is placed under this component. It should be noted that this component overlaps more than often with part task practice, which emphasizes on repetition of learning task to enable automaticity. For the clarification sake, we will place the TMs which support repetition aspect more in the part task practice component.

Supportive Information:

Supportive information is the information provided to support schema construction, the learning and the performance of nonrecurrent aspects of learning tasks, by supporting trainees to deeply process the new information. Supportive information component aims to elaborate the whole task model by establishing non-arbitrary relationships between the new elements and what trainee already knows. Supportive information is usually provided before the task execution and during the task execution if needed which can be on demand or automated depending on the context. Figure 2 allocates all TMs that provide domain level information for support as compared to procedural information provided by the Just in time component.

Procedural Information:

Just in time information is the prerequisite procedural information to the learning and performance of recurrent aspects of learning tasks in a just in time fashion. AR has been frequently found to be well suited to provide procedural information in recurrent task such as an assembly task. In Figure
2, TMs that assist in providing procedural information in a just in time fashion has been categorized under this section.

**Part Task Practice:**

The last component of the 4C/ID model is the *part task practice* which recognizes that some parts of the task are automatic and recurrent. *Part-task practice* items are provided to trainees in order to promote rule automation for selected recurrent aspects of the complex task by means of "strengthening", in which cognitive rules accumulate higher strength on repeated successful executions (Van Merrienboer & Kirschner, 2007). All TMs that facilitate repetition of *learning task* fall under this component.

The WEKIT framework was built upon the WEKIT approach for industrial training to ensure to support for expertise development. By using 4C/ID as the foundation for the framework, different TMs were identified via extensive literature and other approaches mentioned above. These TMs are units of the framework that enables customization of platforms for trainings in various domains to meet the 4C/ID specifications. (For detailed process see Section Operationalization example)

### 4.3. Transfer mechanism

The framework is designed to be flexible enough to be used in different tasks (WEKIT has three different pilot partners in the domain of Medicine, Aeronautics and Space). It manages to achieve this complex goal by building itself upon a pool of TMs. TMs have been kept abstract from the domain, and other factors such as the sensors. By selecting the necessary set of TMs, an end user or trainer can generate TEL platform adhering to the 4C/ID specifications.

TMs are learning design methods that leverage on the expert performance to support expertise development using AR and WT. The term "transfer" is not meant to be taken in a literal meaning. Transferring knowledge as packets from brain to brain is not what we aim to achieve. Rather the word signifies the concept of capturing the expert performance and using it to train the trainee. We also do not claim to capture or explicate expertise which is a complex notion in itself. By capturing expert performance, which are relevant and measurable aspects of a performance, we aim to support the development of expertise in the trainee. The emphasis is on supporting the development, not transferring the expertise such that the trainee will be equivalent of the expert after the training. With that in mind, majority of TMs were extracted from earlier literature (Bibeg et. al, 2017) while some were based on other methods such as interview of experts and observation. Three general characteristics based on our observation of the implementation of TMs which are given below (Table 1). Each TM is characterised by attributes that answer questions such as: "What is the type of skill being trained?" The other characteristics include requirements for recording such as hardware and software and requirements, and for re-enacting by the trainee which may include WT.

<table>
<thead>
<tr>
<th>Description:</th>
<th>How can the features be described?</th>
</tr>
</thead>
<tbody>
<tr>
<td>What skills are being addressed?</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Methods for capture:</th>
<th>How is the mechanism enabled during the recording?</th>
</tr>
</thead>
<tbody>
<tr>
<td>What types of sensors are required?</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Methods for Enactment:</th>
<th>How is this feature enabled by/for the learner?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Which conditions need to be met to allow this feature to be present?</td>
<td></td>
</tr>
<tr>
<td>Which interaction means does the learner have?</td>
<td></td>
</tr>
</tbody>
</table>

**Table 1.** Transfer mechanism characteristics
The list of TMs we have identified through various methods will be outlined below along with the characters of each TM.

1. **Augmented paths**

   **Description:** Augmenting virtual path atop the physical world in a way which allows the trainee to guide the trainee’s motion with precision.

   **Methods for capture:**
   - Tracking of expert’s hand motion
   - Motion sensors and depth cameras

   **Methods for re-enactment:**
   - Visualizing guidance paths using AR
   - Providing haptic or visual feedback
   - Feedback based on capturing expert performance with student performance

2. **Augmented mirrors:**

   **Description:** Augmented display where the trainee can track his/her body, similar to dance rooms.

   **Methods for capture:**
   - Record and track body postures
   - Posture sensor such as Infrared camera and depth cameras

   **Methods for re-enactment:**
   - Large display where the trainee can see himself/herself
   - Posture tracker to provide visual feedback

3. **Highlight object of interest:**

   **Description:** Highlight physical objects in the visual area indicating the trainee that the expert found that object of interest

   **Methods for capture:**
   - Eye tracker and video recording
   - Record gaze behaviour of the expert

   **Methods for re-enactment:**
   - Eye tracker for formative feedback
   - AR display for interventions

4. **Directed focus:**
## 4. Directed focus

*Description:* Visual pointer for expert determined relevant objects outside the visual area of the trainee

<table>
<thead>
<tr>
<th>Methods for capture:</th>
<th>Methods for re-enactment:</th>
</tr>
</thead>
<tbody>
<tr>
<td>✦ Eye tracker and video recording</td>
<td>✦ Eye tracker for formative feedback</td>
</tr>
<tr>
<td>✦ Task analysis</td>
<td>✦ AR display for interventions</td>
</tr>
</tbody>
</table>

## 5. Point of View Video:

*Description:* Provides unique trainee/expert point of view video which may not be available in a third person perspective

<table>
<thead>
<tr>
<th>Methods for capture:</th>
<th>Methods for re-enactment:</th>
</tr>
</thead>
<tbody>
<tr>
<td>✦ Head mounted high definition video recording</td>
<td>✦ Interaction and intervention mechanisms to display the video</td>
</tr>
<tr>
<td>✦ Zoom capabilities in the camera</td>
<td>✦ Possibility to zoom into the recordings</td>
</tr>
</tbody>
</table>

## 6. Think aloud Protocol:

*Description:* Audio recordings present the procedural information or the explanations and mental process (think aloud protocol) of the expert during the task execution

<table>
<thead>
<tr>
<th>Methods for capture:</th>
<th>Methods for re-enactment:</th>
</tr>
</thead>
<tbody>
<tr>
<td>✦ Microphones with noise cancellation</td>
<td>✦ Audio source</td>
</tr>
<tr>
<td>✦ Experts must speak out their thoughts</td>
<td>✦ Inference mechanism to deliver the content when it is needed</td>
</tr>
</tbody>
</table>

## 7. Cues & Clues:

*Description:* Cues and clues are pivots that trigger solution search. It can be in form of image or audio. It should represent the solution with a single annotation

<table>
<thead>
<tr>
<th>Methods for capture:</th>
<th>Methods for re-enactment:</th>
</tr>
</thead>
<tbody>
<tr>
<td>✦ Task Analysis</td>
<td>✦ Anchored to the physical object</td>
</tr>
</tbody>
</table>
8. Annotations:

<table>
<thead>
<tr>
<th>Description: Allow a physical object to be annotated by the expert during task execution. (Similar to sticky notes, but with more modes of information)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methods for capture:</td>
</tr>
<tr>
<td>- Methods to tag media into physical object</td>
</tr>
<tr>
<td>- Manual annotation or done by expert on the fly</td>
</tr>
<tr>
<td>Methods for re-enactment:</td>
</tr>
<tr>
<td>- AR display mechanism to read the annotations</td>
</tr>
<tr>
<td>- Inference mechanism for unobtrusive relay of information</td>
</tr>
</tbody>
</table>

9. Object Enrichment:

<table>
<thead>
<tr>
<th>Description: Provide domain related information about the physical artefact which are crucial to the performance of the task from an expert's point of view</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methods for capture:</td>
</tr>
<tr>
<td>- Use a physical object in real world as anchor</td>
</tr>
<tr>
<td>- Task analysis</td>
</tr>
<tr>
<td>Methods for re-enactment:</td>
</tr>
<tr>
<td>- Mechanism to identify objects in order to display information</td>
</tr>
</tbody>
</table>

10. Contextual Information:

<table>
<thead>
<tr>
<th>Description: Provide information about the procedural information or the process that is frequently changing but is important for performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methods for capture:</td>
</tr>
<tr>
<td>- Knowledge of procedure information that depends on the context and required for the task</td>
</tr>
<tr>
<td>Methods for re-enactment:</td>
</tr>
<tr>
<td>- Method to know when and where to provide the information</td>
</tr>
</tbody>
</table>

11. 3D Models and Animation:
### 12. Interactive virtual objects:

**Description:** Manipulate to practice on virtually objects with physical interactions relying on the 3D models and animation

<table>
<thead>
<tr>
<th>Methods for capture:</th>
<th>Methods for re-enactment:</th>
</tr>
</thead>
</table>
| • Interactive 3D objects and animation where required  
• Task analysis to determine the level of interactivity | • AR to display the 3D models  
• Interaction mechanisms using sensors

### 13. Haptic feedback:

**Description:** Force feedback for perception and manipulation of authentic objects by means of haptic sensor, to provide feedback and guidance.

<table>
<thead>
<tr>
<th>Methods for capture:</th>
<th>Methods for re-enactment:</th>
</tr>
</thead>
</table>
| • Fine motor and motion tracking  
• Task analysis to define criteria for errorless operation | • Fine motor and motion tracking  
• Rotatory directional motors to provide haptic feedback

### 14. X-ray vision:

**Description:** Visualizing the internal process invisible to the eye for enhanced understanding.

<table>
<thead>
<tr>
<th>Methods for capture:</th>
<th>Methods for re-enactment:</th>
</tr>
</thead>
</table>
| • Simulation of the Phenomena  
• Task analysis needed to simulate the phenomena with accurate results | • Visualization of the phenomena atop the physical object  
• Object recognition
15. **Feedback**:

<table>
<thead>
<tr>
<th><strong>15. Feedback</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description:</strong> Feedback is any formative or summative feedback that can be provided by sensors and AR. It is a versatile TM and can be provided in visual or auditory form and should allow meaningful information to be conveyed. Feedback is imperative to any forms of training and should be implemented by consulting the expert during the planning phase.</td>
</tr>
<tr>
<td>Methods for capture:</td>
</tr>
<tr>
<td>• Mechanism to infer mistakes in process based on expert data</td>
</tr>
<tr>
<td>• Mechanism to assess the overall performance</td>
</tr>
</tbody>
</table>

In addition, other TMs have been identified out of the literature via other means such as interview with experts and community participation via Requirements Bazaar (see D1.4). These TMs while not evident in the literature have been highly regarded by the experts and are listed below.

16. **Mobile Control**:

<table>
<thead>
<tr>
<th><strong>16. Mobile control</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description:</strong> Allows execution/visualization of remote action or controls which would otherwise require the need to leave the current work place</td>
</tr>
<tr>
<td>Methods for capture:</td>
</tr>
<tr>
<td>• Task analysis to determine what actions and outputs are relevant</td>
</tr>
<tr>
<td>• Implementation to control devices in mobile manner</td>
</tr>
</tbody>
</table>

17. **Ghost track**:

<table>
<thead>
<tr>
<th><strong>16. Mobile control</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description:</strong> Allows visualization of the whole-body movement of the expert or the earlier recording of the trainee themselves for reflection and imitation</td>
</tr>
<tr>
<td>Methods for capture:</td>
</tr>
<tr>
<td>• Sensors to capture the whole-body movements in a meaningful manner</td>
</tr>
<tr>
<td>• Record of outcomes of the action performed</td>
</tr>
</tbody>
</table>
### 16. Mobile control

**Description:** In instances where a remote expert is needed, it acts as an instant communication channel without having to divert from the work flow.

<table>
<thead>
<tr>
<th>Methods for capture:</th>
<th>Methods for re-enactment:</th>
</tr>
</thead>
<tbody>
<tr>
<td>♦ N/A</td>
<td>♦ Scaffolding may be required to reduce over reliance on the expert</td>
</tr>
<tr>
<td></td>
<td>♦ Communication channel between the expert and the trainee</td>
</tr>
</tbody>
</table>

### 5. Operationalization of the framework

The WEKIT framework provides flexibility to adapt WEKIT industrial training approach to various training domains. The TMs that have been implemented at an abstract level enables the trainer to select a proper set of TMs for the current task being trained. The selection of the TMs are based on the task attributes identified via extensive task analysis. To facilitate the transition from task analysis to the WEKIT platform, TMs have been categorized according to the attributes which the authors of the original literature aimed to train using the TM. The figure below provides a snippet of the document¹ used during the literature review to map the TMs with the attributes (Figure 3).

---

¹ [https://goo.gl/taVJye](https://goo.gl/taVJye)
Attributes of Experts presented in the figure were identified from the literature. The original authors aimed to train this attributes in their study. The framework has further defined these attributes as “Task types” by assigning the following properties which are outlined in Table 2.

**Table 2.** Task type description

<table>
<thead>
<tr>
<th>Task type</th>
<th>Description: what are the most common attributes describing this task?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mastery Condition: what are requirements to be fulfilled for successful task execution?</td>
</tr>
<tr>
<td></td>
<td>Learning difficulties: what are aspects, which makes it hard for novices to learn this task from an expert?</td>
</tr>
<tr>
<td></td>
<td>Traditional teaching means: what are “traditional” means of teaching, that an expert teacher would use to teach these tasks?</td>
</tr>
<tr>
<td></td>
<td>Supported TMs: TMs that support the training of this task type.</td>
</tr>
</tbody>
</table>

The list of Task types that have been identified are as follows.

1. **Perceptual ability:**
   a. Description: Task requiring the perceptions to recognize and predict minute errors during operations and maintenance
   b. Mastery condition: Successful detection of errors and safety complications
   c. Learning difficulties: Vast knowledge and experience with the particular system and their daily functioning
   d. Traditional teaching means: none
e. **Supported TMs:** Highlight Object of Interest, Directed focus, Object enrichment, Point of view video, X-ray vision

2. **High memory:**

   a. **Description:** Successful execution of all steps and reaching the final state
   b. **Mastery condition:** Successful detection of errors and safety complications
   c. **Learning difficulties:** Inability to hold a complex 3D model in spatial Memory and to have all the steps automated
   d. **Traditional teaching means:** Chucking, 4C/ID based instructions
   e. **Supported TMs:** Interactive virtual objects, Highlight objects of interest, Point of view video, Cues and clues, Object enrichment, Feedback, Contextual information

3. **Collaborative ability:**

   a. **Description:** ability to collaborate in a team.
   b. **Mastery condition:** successful cooperation between two persons
   c. **Learning difficulties:** The coordination overhead cost makes it difficult to work in a team
   d. **Traditional teaching means:** coordination protocols, role play, group work
   e. **Supported TMs:** Interactive virtual objects, Point of view video, contextual information, 3D models and animations.

4. **Decision making:**

   a. **Description:** ability to understand, reason and remember the theoretical constructs to apply them practically for making the correct decisions following a decision tree.
   b. **Mastery condition:** Ability to maintain a working simulation or model and relationships in the memory. Successful interpretation of phenomena and improved backtracking to detect errors in past
   c. **Learning difficulties:** Limited working memory
   d. **Traditional teaching means:** providing theoretical base knowledge
   e. **Supported TMs:** Interactive virtual objects, Point of view video, Cues and clues, 3D models and animations, Haptic feedback, Highlight Object of Interest

5. **High speed:**

   a. **Description:** needs to be performed often and routinely, saving small amounts of time per execution may save a large amount overall, deviation is not so critical
   b. **Mastery condition:** execution time should be below a specific threshold for an expert
   c. **Learning difficulties:** experts may execute the task so fast, that novices cannot recognise individual execution steps as separate actions
   d. **Traditional teaching means:** none
   e. **Supported TMs:** Point of view video, Directed Focus

6. **High Precision:**

   a. **Description:** allows only very limited deviation, higher deviation in precision may lead to high follow-up costs or risks (fine psychomotor skills)
   b. **Mastery condition:** level of precision during task execution must guarantee, that deviation stays below tolerance
   c. **Learning difficulties:** learning from an expert e.g. by observation and imitation does not reveal the high precision requirement
   d. **Traditional teaching means:** none
   e. **Supported TMs:** Interactive virtual objects, Haptic feedback, Directed focus, Point of view video, Augmented path, Object enrichment, Feedback, 3D object and animation
7. **High Spatial ability:**

   a. **Description:** Spatial ability or visuo-spatial ability is the capacity to understand, reason and remember the spatial relations among objects or space. It also includes Ability to maintain a working simulation or model and relationships in the memory
   b. **Mastery condition:** Successful interpretation of phenomena and improved backtracking to detect errors in past
   c. **Learning difficulties:** Limited working memory prohibits most novice without the expertise to hold a whole system in brain making it difficult to understand problems and detect errors
   d. **Traditional teaching means:** none
   e. **Supported TMs:** Point of view video, Augmented path, 3D object and animation

Some other attributes that were deemed important by the experts which were not found on the literature have been listed below.

8. **Assertiveness:**

   a. **Description:** Ability to report and observe explicit details
   b. **Mastery condition:** Successful communication of the process till date with accounts for the technician taking over and proper functioning
   c. **Learning difficulties:** developing automation of process to reduce the overhead cost thinking which can be directed to observing other errors which improves by experience
   d. **Traditional teaching means:** none
   e. **Supported TMs:** N/A

9. **Self-awareness:**

   a. **Description:** Possess a certain degree of ability to understand their performance and current state of affairs such as the environment to reflect upon it for improvement. Also be capable adapting to current variables in the environment to change their performance
   b. **Mastery condition:** High degree of situational awareness and consistent performance under various types of changes
   c. **Learning difficulties:** Vast experience to develop situational awareness and difficulty to replicate all random issues during practice
   d. **Traditional teaching means:** none
   e. **Supported TMs:** Feedback

5.1. **Operationalization example**

In this section, we will present a scenario from one of the WEKIT trails from the perspective of the framework. This section is meant to provide an overview of how the framework is intended to be operationalized at the current state. The complex task "Pre-flight inspection" task was broken into 10 subtasks (further details about the task can be found in D6.1). The first subtask, “Ensuring that the baggage compartment is secured” was chosen to have task analysis performed which revealed a set of attributes supported by each task type.

**Task types:** Perceptual ability is required in the technician performing the preflight inspection task to be able to detect errors by means of observation. Similarly, High memory is also required to remember all the specifications regarding the task to be performed. In addition, in case of error detection, the technician is required to be assertive. Experts also mentioned technicians are usually put through long hours resulting in fatigue. This may cause the technician to overlook details and thus they must be self-aware of their current state and their surroundings to avoid the risk associated with the task.
Transfer Mechanisms: Based on the task types Directed focus, Point of view video was used to train the perception of the trainer. Contextual information and Think aloud protocol was implemented in assist with memory. A checklist of the task needed to perform was provided for supporting the assertiveness of the trainee. However, self-awareness was not implemented due to lack of biosensors and other necessary equipment in the WEKIT prototype during the trial. TMs such as Feedback may be selected based on expert’s opinion.

Capture: Each TM possess a set of recording requirements. After ensuring that all recording requirements are met, the expert will record the procedure ensuring that all the relevant information required to execute the TMs in the player are recorded. Following a successful capture of data from the recorder, the player will provide the trainee with all the relevant information required to perform the task. Some information may not be available through the expert. Such information must be identified through the task analysis or through collective analysis of the sensor reading. For example, self-awareness can be provided through the feedback. However, self-awareness requires biosensors to be assessed which may require customization to each individual user. Performing task analysis may help us define the threshold WEKIT plans to perform a series of small scale experiments to successfully implement these sensors at an abstract level.

Re-enactment: The trainee uses AR glasses which is used to project the captured data. Depending on the set of re-enactment requirements identified from the task types and TMs, proper sensor set up may be selected to track the trainee performance. TMs such as Feedback will provide formative feedback by using sensor readings.

Reflection: By comparing the expert performance with the trainee performance, summative feedback may be provided. Comparison will be done between the current performance and earlier performance to facilitate self-reflection. The trainee performance record will be used by the expert to provide qualitative feedback.

6. Reflection from Trials

During the first WEKIT trials, the adherence of the WEKIT technical implementation to the framework was evaluated. Details of the trail can be found in D6.1, D6.2 & D6.3. The trials were a major stepping stone for improvement of the framework. More importantly, the trial allowed us to collect perspective of both trainers and trainee about the framework. Data collected during the trials will be used to reflect on the shortcomings of the current state of the framework and inform the future progress. Some of the data collected from the trials have been presented below. In the framework section of the questionnaire, trainee and experts were asked to rate each statement that represented an ideal implementation of the TM on a Likert scale of 1-7 based on their experience after using the prototype.
The experts’ overall perception of TMs during all the trials was found to be positive in average. In the Figure, the later trials in Altec and Ebit were reported much more positively than Lufttransport trial (Figure 4). The usability of the prototype was improved over each trial. Proper pre-instructions for the participants was also crafted collecting from the experience from the first trial which contributed to the overall experience. A major contributing factor to the lower rating from the Lufttransport case can also be a result from the difficulty to use many other TMs in a dark and confined cabin space. Our observation of the expert’s point of view video from HoloLens showed that most experts relied on audio recordings only which was the simplest and hassle free to record. It should be noted that the experts were mainly exposed to the recorder. Though they were also exposed to the player briefly to let them envision how the recorder data is being used. However, questionnaire related to the framework were, by nature, more oriented to the player and the students.

Similar to the experts’ data, the response in the second and the third trials were more positive in average. However, the highest perceived ratings of the students in each of the trials varied. This was
as the framework predicted due the differences in required attributes between the domains. At the same time, some of the TMs were perceived equally among all three trials which could hint that such TMs can applicable across all domains. In Figure, Think Aloud (TA1 and TA2) were reported with huge difference between the two questions (Figure 5). However, TA2 asked if the participant understood reasoning behind the expert’s instructions while most experts during the trials did not made efforts to be explicit.

7. Future work

The framework development is an ongoing process. It is evident that the framework is incomplete in its current state. As we explore the horizons in WEKIT, more TMs and Task types will be added to cater to boarder and more complete training scenarios. TMs description and structure themselves will be improved to provide a clear application scenarios and guidelines. Some of the TMs lack a clear boundary and overlap between different components of the 4C/ID model. Further exploration is required to define these TMs and Task types such that they provide a concrete structure. Doing so will enable better comprehension of the framework by trainee and instructional designers. As such, we also aim to produce a section dedicated to adaptation of the framework for non WEKIT individuals. This section will help the trainers transition from their traditional training to WEKIT based training approach.

During the first WEKIT trails, only the adherence of the technical implementation to the framework was tested. In future trials, other factors such as learning outcomes and efficiency will also be tested with control groups. Lessons learnt from the first trials will be adapted to the future trails for more structured and transparent assessment of the framework. Some TMs such as haptic feedback which were clearly not implemented were also positively reported. This could be the result of the novelty effect, lack of motivation to complete long questionnaires or complexity of the questionnaire. Adapting new forms of assessment as compared to the questionnaire we used, the data quality will be improved with better scientific items and stealth assessments.

The data collected from the trails have also provided useful insights. Selection of TMs depending on the domains will be more informed as compared to earlier method of using "house of quality" to determine the importance of the TM. Implementations of the TMs to meet the framework specifications will be streamlined. Some implemented TMs were not perceived as highly as the experts envisioned. Think aloud protocol while fully implemented did not result in students understanding the task. This is due to experts not involved in training during the trials or lack of real life training situation for the trainer. Therefore, we will also reflect on the overall experimentation procedure during the trials. We aim for a better integration with the requirements capturing and improvement processes by further leveraging Requirements Bazaar through the WEKIT Community. In this direction, we are currently investigating methods to embed capturing user feedback through the wearable devices while record and replay.

Finally, other relevant work packages will be better streamlined to the framework development. Doing so will enable the progress of other packages to closely meet the specifications of the framework. It will also enable the framework to adapt to the changes and needs of other stakeholders while keep the work packages informed of each other updates. The framework will address the self-awareness and reflection based on the planned trails. These trails will address the bio sensors and other sensors that provide data relevant to the current state of the trainee or the environment. Proper methodologies regarding interpretation and use of data from such sensors will be tested and evaluated with close co-operation among WEKIT members and the domain experts. At current state, biosensor data are extremely personal data. With similar readings providing different interpretations varying from individual to individual, there is a need to customize the sensors repeatedly making an abstract implementation difficult to achieve.
8. Conclusions

The WEKIT framework manages to address many instructional challenges in the project. For example, the need to address various domains was approached by an abstract approach of defining TMs. The framework manages to utilize the full potential of the technology while being able to stay abstract from the tools used to perform the task. Similarly, the framework defines guidelines based on 4C/ID to ensure that the experts are being utilized to the full potential without compromising the training of the trainee.

Eventually, the work done so far has presented potential and many opportunities for further development and research. Even though several milestones have been met in the development of the framework, limitations exist. The system, with the current technological and research, limitations will not be a substitute of the expert. The framework itself is designed to be a support for training where expert as resources are limited. The need to perform an extensive task analysis on the domain exist. There is no evidence of explicating expertise and we do not claim to do so. While explicating the tacit knowledge is possible by rigorous manual means, by nature it cannot be done unobtrusively. Instead WEKIT will leverage on the performance metrics of the expert and visible attributes of expert performance to support the expertise development in the trainee.

The work on the framework is still ongoing. Various experiments in future have been planned to further develop and analyse the framework. The list of TMs and Task types is not extensive and will be updated as new findings and technology are revealed. TMs and Task types will be more clearly defined to make the framework more concrete to meet 4C/ID specifications. Effort is needed to make the operationalization aspect of the framework less complicated.
9. Bibliography


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