D1.7 WEKIT
Framework & Training Methodology

The WEKIT Framework
Revision History

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<th>Version</th>
<th>Date</th>
<th>Contributor(s)</th>
<th>Modification</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>18.03.2019</td>
<td>Bibeg Hang Limbu</td>
<td>First complete version</td>
</tr>
<tr>
<td>0.2</td>
<td>19.03.2019</td>
<td>Roland Klemke</td>
<td>Editing and modifications</td>
</tr>
<tr>
<td>0.3</td>
<td>20.03.2019</td>
<td>Fridolin Wild</td>
<td>Review version</td>
</tr>
<tr>
<td>1.0</td>
<td>21.03.2019</td>
<td>Bibeg Hang Limbu</td>
<td>Final version</td>
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WEKIT Framework and Training Methodology

WP 1.3 | D1.5 | D1.7

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Deliverable number D1.7
Dissemination level Public
Version 1.0
Status final
Date 21.03.2019
Due date 28.02.2019
**WEKIT Abbreviations**

<table>
<thead>
<tr>
<th>WP</th>
<th>Work Package</th>
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<tr>
<td>AR</td>
<td>Augmented Reality</td>
</tr>
<tr>
<td>WT</td>
<td>Wearable Technology</td>
</tr>
<tr>
<td>IDM</td>
<td>Instructional Design Methods</td>
</tr>
<tr>
<td>WS</td>
<td>Wearable Sensors</td>
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</table>
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1) Executive summary

The document reports on the status of the WEKIT framework as seen by key stakeholders, e.g. self-directed learners, instructional designers, trainers, trainees, managers, application domain experts, standards teams. Building on the methodology described in D1.5, it outlines the work done and progress made so far in the Task 1.3. The WEKIT framework guides and supports the development and implementation of the augmented reality platforms for training using experts. It supports the transition of the trainers from the traditional training platform to the WEKIT approach. It also supports the instructional designers in designing the optimal training system using augmented reality and wearable sensors.

The framework builds upon a pool of learning design methods for Augmented Reality and Wearable Technology that capture expert performance and make available the expert’s knowledge and experience to trainees. It provides a methodological approach to use these learning design methods for designing an optimal training platform and scaffolds an optimal recording and training methodology.

The framework was built and refined by performing an extensive literature review as mentioned in D1.5, 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. At the same time, the framework is meant to be domain independent and abstract, such that it can be used in different domains for training.

The framework itself has been detailed in D1.3 and D1.4. In D1.5, the experts evaluated how well each aspect of the framework was implemented and refined in the wekit.one prototype. During this study, the experts used the recorder and rated statements that corresponded to implementation of the (Transfer Mechanisms) units of the framework. The results showed satisfactory response from the experts. The focus of this document, D1.7, will be on the operationalization of the framework and results from the second WEKIT trial. During the second trial, experts evaluated the expert model (Expert recording) after using the player. The results show satisfactory reactions by the experts. The document will act as a “manual” for future trainers, system designers and researchers. Section 2 of the documents reports on the current status of the framework followed by section 3 on operationalization of the framework. Section 4 of the document reflects on data collected from the recent trials followed by conclusion and future work.
2) WEKIT Framework

The WEKIT framework supports capture of expert performance using wearable sensors (WS) and augmented reality (AR) for creating expert like guidance and feedback for training. WS have the capability to unobtrusively measure and record physical properties, while AR provides a rich multimodal and multisensory medium (Azuma et al., 2001) for trainees to learn from the captured expert performance. WS and AR have been successfully used in training to provide feedback based on expert data (e.g., Schneider et al., 2017). The WEKIT framework exploits this potential of WS and AR for supporting training. It addresses the shortage of experts for personalized one to one training by simulating expert performance data based guidance and feedback which is crucial for expertise development.

The WEKIT framework is extensible to support emerging and evolving needs and methods, e.g. it supports training by providing a scaffold for instructional designers to design applications and providing experts with a methodological approach for using the application to record optimally. The framework ensures that the recorded expert model using the application is optimal for training. To ensure that the expert model is optimal, the framework takes into account various theoretical factors such as, the difficulty of learning from an expert (Hinds, 1999). Moreover, experts are often unaware of all the knowledge behind their superior performance (Patterson et al., 2010). To mitigate these issues, the WEKIT framework adapts the Four Component Instructional Design (4C/ID) model, which supports didactic approach to development of expertise, by facilitating the model with AR and WS based Instructional Design Methods (IDMs, which were previously known as Transfer Mechanisms, TM1). Sarfo & Elen (2007) and Neelen & Kirschner (2016) positively reported 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. Evidence about the effectiveness of training environments designed in line with specifications of the 4C/ID model for promoting development of expertise in training contexts has also been documented by Merriënboer and Paas (2003), and Merrill (2002). The WEKIT framework scaffolds the recording and replaying procedure with AR and WS to ensure that 4C/ID requirements are met.

The WEKIT framework bridges the pedagogical aspects of 4C/ID model with the affordances of AR and WS. IDMs are learning design methods that leverage on the expert performance to support expertise development using AR and WS. The basic assumption of the 4C/ID model is that all complex learning can be represented in combination of four components (Learning Tasks, Supportive Information, Procedural Information and Part-Task Practice) described by the model (van Merriënboer & Kester, 2014). The WEKIT framework supplements the four components of the model with IDMs (Fig. 1), which enables instructional designers and trainers to implement pedagogically sound AR and WS supported training. Figure 1 lists the IDMs that support each component of the 4C/ID model. The first component Learning tasks are authentic, whole task experiences that are provided to the trainee in order to promote schema construction for non-recurrent aspects of the task (van Merriënboer, et al., 2002). Supportive information is the information provided to support schema construction, the learning and the performance of non-recurrent aspects of learning tasks, which are provided in a just-in-time fashion. Procedural information is the prerequisite information to the learning and performance of recurrent aspects of learning tasks, which are provided to trainees for promoting rule automation (Kirschner & van Merrienboer, 2008).

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1 For reasons of consistency with previous WEKIT deliverables and publications, we still use TM for numbering the instructional design methods, while referring to them as IDMs in the written text.
2.1 Instructional Design Mechanisms

The IDMs allow the WEKIT framework to be used in different types of tasks. IDMs are instructional design methods that utilize the affordances of AR and WS to support training using expert performance data. IDMs are abstracted from the domain, and other factors such as the particular AR hardware and vendor sensors. The majority of IDMs were extracted from earlier literature by conducting a review of recent studies that exploited AR and WS for training (B. Limbu et al., 2018).

We identified three general characteristics of IDMs based on our observation of the implementation of IDMs which are given below (Table 1). Each IDM is characterized by a description that answers 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 apprentice which may include WS. Some of the IDMs identified have been presented in Tables (2&3) below.

**Table 1.** Instructional design mechanism characteristics

<table>
<thead>
<tr>
<th>Description:</th>
</tr>
</thead>
<tbody>
<tr>
<td>How can the features be described?</td>
</tr>
<tr>
<td>What skills are being addressed?</td>
</tr>
</tbody>
</table>
Methods for capture:
How is the mechanism enabled during the recording?
What types of sensors are required?

Methods for Enactment:
Which conditions need to be met to allow this feature to be present?
Which interaction means does the learner have?
What type of sensor/display technology does the learner require?
How is this feature enabled by/for the learner?

Table 2 consist of IDMs which require demonstration of the task from the expert, during which the WS record his/her performance

Table 2. IDMs that use expert demonstration

<table>
<thead>
<tr>
<th>Description:</th>
<th>Capture Methods:</th>
<th>Re-enactment Methods:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TM 01: Augmented paths</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Augmenting virtual path atop the physical world in a way which allows the trainee to guide his/her motion with precision.</td>
<td>● Motion sensors and depth cameras ● Tracking of positional data</td>
<td>● Visualizing guidance paths using AR ● Providing haptic or visual feedback based expert performance data</td>
</tr>
<tr>
<td><strong>TM 02: Augmented mirrors</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Augmented display where trainees can track their body postures.</td>
<td>● Tracking of postures Posture sensor such as Infrared camera and infrared cameras</td>
<td>● Large display where the trainee can see himself/herself ● Posture tracker to provide feedback</td>
</tr>
<tr>
<td><strong>TM 03: Directed Focus</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual pointer for relevant objects outside the visual area of the trainee</td>
<td>● Eye tracker and video recording ● Task analysis for pointing to the next location</td>
<td>● Eye tracker for formative feedback ● AR display for feedback</td>
</tr>
</tbody>
</table>

The markers direct the trainee to the relevant areas.
### TM 04: Point of View Video

Provides expert point-of-view video which may provide perspectives not available in a third person.

- Head mounted high definition video recording
- Zoom capabilities in the camera
- Interaction mechanisms to display the video
- Possibility to zoom into the recordings

The trainee is displayed with the point of view perspective video recorded by the expert.

### TM 05: Annotations

Allow a physical object to be annotated by the expert during task execution (similar to sticky notes but with more modalities)

- Methods to tag media into physical object
- Manual annotation or done by expert on the fly
- AR display mechanism to read the annotations
- Mechanism for unobtrusive playback of information

A physical object is annotated by the expert with an image to allow the trainee to recognize the image.
### TM 06: Ghost track

<table>
<thead>
<tr>
<th>Allows visualization of the whole-body movement of the expert or the earlier recording of the trainees themselves for imitation and reflection</th>
<th>Sensors to capture the whole-body movements</th>
<th>Visualization mechanisms</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Recording of results of the action performed by the expert</td>
<td>Tracking of current state for feedback and evaluation</td>
</tr>
</tbody>
</table>

An expert’s body and hand movement is recorded and replayed as ghost track.

### TM 07: Highlight object of interest

<table>
<thead>
<tr>
<th>Highlight physical objects in the visual area indicating to the trainee that the expert marked it as an object of interest</th>
<th>Eye tracker and video recording</th>
<th>AR display for interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Record gaze behavior of the expert</td>
<td>Manual tagging of the physical object as relevant</td>
</tr>
</tbody>
</table>

The button on the machine is highlighted as a object of interest.
TM 08: Cues & Clues

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

- Task Analysis
- Mechanism to allow content creation to be used for clues and cues
- AR displays the clues anchored to the physical object
- Additional help when requested

A clue is left by the expert for the trainee in form of a text.

Table 3 consists of IDMs that require modelling of the expert manually by using Task Analysis techniques such as interviews or other methods for extracting experts knowledge.

**Table 3.** IDMs which uses expert modelling

<table>
<thead>
<tr>
<th>Description:</th>
<th>Capture methods:</th>
<th>Enactment Methods:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TM 09: Object Enrichment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Virtually amplify the effect of the process to enable trainees to understand the consequences of certain events or actions in the process which may be too subtle to notice</td>
<td>● Task analysis</td>
<td>● Mechanism such as animations or interventions to makes the effect more observable</td>
</tr>
<tr>
<td><strong>TM 10: Contextual Information</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Provide information about the process that is frequently changing but is important for performance

- Task analysis to know where knowledge of the process is important
- Method to know when and where to provide the information
- Mechanism to provide the information to the trainee

**TM 11: 3D Models and Animation**

3d models and animations assist in easy interpretation of complex models and phenomena which require high spatial processing ability

- 3D objects and animation where required
- Mechanism to be anchored to real world by the expert
- AR display for the 3d models
- Interaction mechanisms using sensors to

A 3d model is placed along the original device

**TM 12: Interactive virtual objects**

Interactable virtual objects to practice with physical interactions relying on the 3d models and animation

- Interactive 3D objects and animation where required
- Task analysis to determine the level of interactivity
- Sensors for motion recording

**TM 13: Haptic feedback**

Lightweight force feedback for perception and manipulation of authentic objects by means of haptic sensor, to provide feedback and guidance

- Fine motor and motion tracking
- Task analysis to define criteria for errorless operation
- Fine motor and motion tracking
- Rotary directional motors to provide haptic feedback

**TM 14: X-ray vision**

Visualizing objects and processes that are hidden behind physical surfaces and invisible to the eye for enhanced understanding

- Task analysis needed to simulate the process being visualized with accurate results
- Visualization of the phenomena atop the physical object
- Object recognition

**TM 15: Summative Feedback**
Summative feedback is a versatile TM that is provided at the end of each practice session. It should allow reflection on the current performance.

- Mechanism to infer mistakes in process based on expert data
- Track the attributes on which the performance is judged
- Mechanism to assess the overall performance

**TM 17: Formative Feedback**

Formative feedback is any lightweight feedback that can be provided by sensors and AR. It could be provided in visual, auditory or haptic form and should assist in conveying the procedural information.

- Recording of any relevant sensor data in a meaningful manner such that it can be used for comparison with incoming stream of data.
- Measure trainee performance based on attributes

The list of IDMs identified through various methods (Limbu et al., 2018) is outlined above along with their characteristics. The first group includes IDMs that require expert to demonstrate a task that allows sensors to capture his/her performance. The second group includes TMs that modelled the expert using various manual task analysis methods. The list is not exhaustive and will only grow as technology improves. In the following section we provide insight on how to use these IDMs to capture expert performance for training with an example on how to operationalize the framework.

### 3) Operationalization

The WEKIT framework is designed to be flexible in order to adopt it to various training domains. It supports the trainer to select a proper set of IDMs for the current task being trained. The selection of the IDMs is based on the task attributes identified via extensive task analysis of the task to be performed. To facilitate the transition from task analysis to the WEKIT platform, IDMs have been categorized according to the skills that the authors of the original literature aimed to train using the IDM (Limbu et al., 2018). The figure below provides classification of the IDMs with the attributes (Figure 2).

<table>
<thead>
<tr>
<th>Attributes of an expert</th>
<th>Motor skills</th>
<th>Cognitive skills</th>
<th>Collaborative skills</th>
<th>Perceptual skills</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Learning task</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TM 01: Augmented path</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TM 02: Augmented mirror</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TM 11: Interactive virtual objects</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>TM 17: Mobile control</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Supportive information</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TM 04: POV videos</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>TM 05: Annotation</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 2. Mapping of IDMs with skills that can be trained

Figure 3 assists the instructional designers and trainers to select the best set of IDMs for their use case. Once the IDMs are selected, the information in Tables 2, 3, and 4 can assist them to implement the system. However, before all this is done, the use case must be analysed to extract important attributes of the task. This can be done with the help of task analysis or a domain expert. The task can then be structured according to the framework’s 4C/ID approach for training. The list of steps or guidelines are provided in the following section.

Guidelines/Steps to implementing the framework

The framework is designed to be abstracted from the domain of application. Thus, it is crucial to perform task analysis of the task to be trained by involving an expert in the domain. Task analysis can be done using interviews or other methods. Below, we provide a set of guidelines along with an example from the WEKIT space case (D 6.9) to assist in implementing the framework.

Use case description:

In this scenario, an astronaut will prepare a rover to be used on the Mars or the Moon surface for exploration tasks. The crew training concepts and tools supporting the exploration missions will be taken into account.

1. Design learning task: Break the complex task into a set of sub tasks and determine the performance attributes such as mentioned in Figure 2, for each sub task. A subtask is a fundamental task that constitutes the whole complex task and can represent a skill. Subtasks may be routine or non-routine. Routine tasks may benefit from TMs in Learning task category such as interactive virtual objects however, authentic tasks should be preferred where possible. IT may be supplemented by

<table>
<thead>
<tr>
<th>IDM</th>
<th>✔</th>
<th>✔</th>
<th>✔</th>
<th>✔</th>
</tr>
</thead>
<tbody>
<tr>
<td>TM 06: Cues &amp; clues</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>TM 09: Contextual information</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>TM 10: 3D models &amp; animation</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>TM 13: X-ray vision</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
</tbody>
</table>

Procedural information

- TM 03: Directed Focus
- TM 06: Highlight Objects
- TM 08: Object enrichment
- TM 12: Haptic feedback
- TM 16: Formative feedback

Part task practice

- TM 17: Ghost track
- TM 18: Summative feedback
TMs in Part task section such as Ghost track for quick progress. Non-routine tasks are best left to authentic scenarios as they are better learnt in this manner.

2. Sequence the task: As complex task usually comprises more than one subtasks, it should be ordered in progression of increasing difficulty. However, the sequence of task should support variability of practice for better learning (van Merriënboer, et al., 2002). It should be projected into the learning plan that when the apprentice finishes the last task in the list he/she would have mastered the task.

3. Determine performance objectives: Criteria for allowing the apprentice to progress to the next subtask should be outlined. This also helps in focusing the type of feedback that can be provided.

4. Design supportive information: Information that helps apprentices perform the non-recurrent aspects of the subtask is determined. This step should generate content that the expert will not be able to create or overlook during the recording of expert performance as “non-recurrent task, may not occur”. Supportive information can be provided using one of the IDMs in the supportive information category, depending on the nature of information. Supportive information is usually only provided when requested so as not to over-crowd the AR vision of the apprentice.

5. Record expert performance: Based on the subtask and its attributes, proper sets of TMs from the learning task category are selected. Each TM consists of sets of recording requirements, which should be met. The expert proceeds after wearing all the sensors and being able to demonstrate the subtask. The sensor records all the information and generates the learning content, which supports the procedural task. It should be noted, when recurrent tasks are practiced, procedural information should be scaffolded. Procedural information should be provided only when needed or requested during the practice.

6. Train in same/similar environment: It is crucial that re-enactment of the learning task is done in the same or closely similar environment. Technical requirements aside, it also helps in learning of the task by the apprentice without any overhead load.

7. Follow through reflection: The system can provide feedback on procedural task, but it does not replace the expert. Providing the expert with logged data of every apprentice’s performance in a simple readable format will facilitate the learning process.

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 pre-flight 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.

**Instructional Design 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 to assist with memory. A checklist of the task needed to perform was provided for supporting the assertiveness of the trainee. However, self-awareness support was not implemented due to lack of biosensors and other necessary equipment in the WEKIT prototype during the trial. IDMs such as Feedback may be selected based on expert's opinion.

**Capture:** Each IDM possesses 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 for executing the IDMs 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. IDMs 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.

### 4) Results from Trials

During this trials, we aimed to evaluate the expert model that was captured by using the wekit.one software and hence, its affordances. The Wekit.one software was evaluated in the earlier trial by the experts as having met the criteria of implementing the framework. To do so, we created an expert model of the procedure with an expert who was familiar with the software and the procedure to be taught. This model was then peer-evaluated by the other experts without post-processing. The aim of this expert model evaluation questionnaire (EMEQ), based on Jucks, Schulte-Löbbert, & Bromme (2007), was to peer-evaluate the expert model (recording of the expert), by judging its fitness for the purpose via other experts (recording of the expert). The participants responded by selecting from 1 (strongly disagree) to 7 (strongly agree). This expert model was facilitated by the affordances of the wekit.one Recorder application and therefore co-relates to the extent to which the application enables effective recording of the expert. N=61 expert responses were included in the study after removing those participants who did not use the player and those who did not come directly from the domain. There were 14 female and 47 male expert participants, with the majority of them falling in the age range of 25-34 and 35-44. Among these participants, there were 8 supervisor, 8 trainers, 31 engineers and 19 from various other roles. 32 expert participants had more than 10 years of experience, 20 had less than 5 years and 9 between 5-10 years.
Figure 3 summarises all expert responses across the three trials, while figure 4 displays the descriptive statistics for all responses. Figure 4 also lists the original questions asked as part of the EMEQ.

The average mean and median response of experts across all trials for all the times were above average. Only 5 expert participants scored EMEQ 1 as 4, taking a neutral stance on the importance for the students to understand what each key concept meant. The expert participants rated EMEQ 2 between 4-7. There is a strong agreement between expert participants who rated EMEQ 3, EMEQ 5 and EMEQ 7 between 5-7, while one expert participant each rated EMEQ 3 and EMEQ 5 a score of 3 and 2 expert participant rated EMEQ 7 a score of 3. This verifies that the expert model explained the procedure in comprehensible terms and included all information required for the procedure. Similarly expert participants rated EMEQ 4, EMEQ 6 and EMEQ 8 between 4-7. Only 2 experts rated the items EMEQ 4 and EMEQ 6 below 4 and 3 expert participants rated EMEQ 8 below 4. This verifies that the procedure was explained in enough detail, just in time and in an unobtrusive manner. Expert Participants rated EMEQ 9 & EMEQ 10 between 4-7. 6 Expert participants rated EMEQ 9 below 4 and 3 expert participants rated EMEQ 10 below 4. The expert model can arguably guide students to the correct location and items in the physical space. EMEQ 11 was rated between 1-7 with lower quartile rating the item between 1-4. Experts’ opinions vary hugely in terms of how well and often critical dynamic information were updated.
Descriptive Statistics

<table>
<thead>
<tr>
<th>EMEQ</th>
<th>Description</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMEQ 1</td>
<td>[It is important that the student knows what each key concept means.]</td>
<td>61</td>
<td>6.0656</td>
<td>.83404</td>
</tr>
<tr>
<td>EMEQ 2</td>
<td>[For this student, all key concepts are defined just in time.]</td>
<td>61</td>
<td>5.5738</td>
<td>.88429</td>
</tr>
<tr>
<td>EMEQ 3</td>
<td>[For this student, the procedure is explained in comprehensible enough terms.]</td>
<td>61</td>
<td>5.9180</td>
<td>.78092</td>
</tr>
<tr>
<td>EMEQ 4</td>
<td>[For this student, the procedure is explained in enough detail.]</td>
<td>61</td>
<td>5.7049</td>
<td>.88212</td>
</tr>
<tr>
<td>EMEQ 5</td>
<td>[All the information that the student needs to follow the procedure is contained.]</td>
<td>61</td>
<td>5.8525</td>
<td>.81314</td>
</tr>
<tr>
<td>EMEQ 6</td>
<td>[All the information that the student needs to follow the procedure is provided just in time.]</td>
<td>61</td>
<td>5.5738</td>
<td>.99094</td>
</tr>
<tr>
<td>EMEQ 7</td>
<td>[All the contained information is important to the student]</td>
<td>61</td>
<td>5.7869</td>
<td>.95070</td>
</tr>
<tr>
<td>EMEQ 8</td>
<td>[All the information provided is non-obtrusive for the student.]</td>
<td>61</td>
<td>5.6393</td>
<td>.96666</td>
</tr>
<tr>
<td>EMEQ 9</td>
<td>[All the objects/items required by the student in the procedure is easily located/identified]</td>
<td>61</td>
<td>5.5738</td>
<td>1.20359</td>
</tr>
<tr>
<td>EMEQ 10</td>
<td>[It is clear for the student which physical area to move next.]</td>
<td>61</td>
<td>5.4590</td>
<td>.99287</td>
</tr>
<tr>
<td>EMEQ 11</td>
<td>[All relevant information that is frequently updated, such as temperature, is made aware to the student.]</td>
<td>61</td>
<td>4.7869</td>
<td>1.17068</td>
</tr>
</tbody>
</table>

Valid N (listwise) 61

Fig. 4. Descriptive statistics for EMEQ responses

The individual reports for each trial can be found in D 6.10, D 6.11 & D 6.12. The figure below provides an overview of the scores for independent trial outcomes. One-way ANCOVA was conducted to determine statistically significant difference between Lufttransport, Ebit, and Altec trails on EMEQ items based on the trails that the expert participants took part in. There is no significant effect of trials participated by experts on EMEQ 1 \( F(1, 59)=3.126, P=.082 \), EMEQ 2 \( F(1, 59)=.175, P=.667 \), EMEQ 3 \( F(1, 59)=1.905, P=.300 \), EMEQ 4 \( F(1, 59)=3.720, P=.059 \), EMEQ 5 \( F(1, 59)=1.281, P=.262 \), EMEQ 6 \( F(1, 59)=1.423, P=.238 \), EMEQ 7 \( F(1, 59)=.792, P=.377 \), EMEQ 8 \( F(1, 59)=.049, P=.826 \), EMEQ 9 \( F(1, 59)=2.466, P=.122 \), EMEQ 10 \( F(1, 59)=.104, P=.746 \), EMEQ 11 \( F(1, 59)=.093, P=.762 \), which shows that the mean for each item across all three groups are similar. This supports the statement that the WEKIT.one software is capable of recording equally-effective expert models independent of the use case.
Fig. 5. Expert responses in the three trials
5) Conclusion

The goal of D1.7 is to report on the current status of the WEKIT framework. The WEKIT framework supports the theoretically sound application of AR and WS technologies in the context of training, using experts as resources. It supports development of platforms for experts to create training, which the students can download and train with. The framework had to achieve this goal while being independent of the domain and hardware. The WEKIT framework addressed many such challenges in the project. For example, the need to address various domains was approached by an abstract approach of defining IDMs. Similarly, the framework defines guidelines based on 4C/ID to ensure that the experts are being utilized to their full potential with minimal compromises in the training. This document has presented the current state of the framework, along with operationalization examples and guides. The D1.3, D1.5 and D1.7 together have documented the development of the framework over the life span of the project.

The framework’s relevant results from the recent trials have also been reported here. The results from the trials show that the application developed with the framework can be used to record expert models in most domains with minimal effort on the expert for post processing. During the trials, the expert model was peer-reviewed by the other experts but there was no direct review of the model from the students’ perspective. While the knowledge assessment results in individual trials show none to very little significant difference in the learning performance of students who used WEKIT.one and those who didn’t, the assessment didn’t take pre-knowledge and other factors into account.

It is almost certain that in the future, the list of IDMs and task types is not exhaustive and will be updated as new findings and technology are revealed. IDMs 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 and more elaborate as technology improves and more exploration is done.

6) Future Work

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 apply. Any such AR training system, with the current technological and research limitations will not be able to fully substitute the expert. The framework itself is designed to be a support for training where expert resources are limited. The need to perform an extensive task analysis on the domain still persists and is resource-intensive. This can be addressed for standard content by developing strict guidelines, but, as WEKIT framework strives to be domain-independent, it is not possible to define a single one at this stage.

While explicating tacit knowledge is possible using guided capture as proposed by WEKIT, by nature this cannot be done completely unobtrusively. WEKIT leverages on the performance metrics of the expert and harvests visible attributes of expert performance to support expertise development of the trainee. The development of the applications, and the trials conducted, have focused only on didactic methods. No summative and formative feedback was collected based on expert data. Providing such feedback, especially formative, requires further research on both technology and methodology.
Bibliography


