Managing Affective-learning THrough Intelligent atoms and Smart InteractionS

D5.5 Description of the mobile layer

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Abstract:	D5.5 describes all the components of the MaTHiSiS system that are implemented on the mobile devices following the revised architecture. The relevant software code is available on the MaTHiSiS space at gitlab.
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List of Acronyms

Abbreviation / acronym	Description
AIR	Affect and Intent Recognition
API	Application Programming Interface
ASC	Autism Spectrum Case
ASD	Autism Spectrum Disorder
BP1	Business Process 1 Learning Experience
CGDLC	Career Guidance Distance Learning Case
CLS	Cloud-based Learner's Space
DAT	Data Acquisition Tool
DoW/DoA	Description of Work/Action
DSS	Decision Support System
EE	Experience Engine
I/O	Input / Output
IPA	Interactions with Platform Agents
IWB	Interactive Whiteboard
ITC	Industrial Training Case
LES	Learning Experience Supervisor
LM	Learning Material
LMF	Learning Materialisation Framework
LPR	Learner's Profile Repository
MEC	Mainstream Education Case
MF	MaTHiSiS Front-end
PA	Platform Agents
PC	Platform Configuration
PMLDC	Profound and Multiple Learning Disabilities Case
SC	Sensorial Component
SLA	Smart Learning Atom
SO	Scientific Objective

Abbreviation / acronym	Description
UI	User Interface
UM-T	Users Management Tool
URM	User and Role Manager
xAPI	Experience API

Table 1: Definitions, Acronyms and Abbreviations

Project Description

MATHISIS is a 36-month duration project co-funded by the European Commission Horizon 2020 Programme (H2020-ICT-2015) under Grant Agreement No. 687772. It started on 1st January 2016.

One of the core objectives of MaTHiSiS project is to enhance learning environments and make use of computing devices in learning in a more interactive way, which will provide a product-system to be used in formal, non-formal and informal education. An ecosystem for assisting learners/tutors/caregivers for both regular learners and learners with special needs will be introduced and validated in 5 use cases: Autism Spectrum Case (ASC), Profound and Multiple Learning Disabilities Case (PMLDC), Mainstream Education Case (MEC), Industrial Training Case (ITC) and Career Guidance Distance Learning Case (CGDLC).

MaTHiSiS product-system consists of an integrated platform, along with a set of re-usable learning components (educational material, digital educational artefacts, etc.), which will respond to the needs of a future educational framework, and provide capabilities for: i) adaptive learning, ii) automatic feedback, iii) automatic assessment of learner's progress and behavioural state, iv) affective learning and v) game-based learning.

Within MaTHiSiS, an innovative structural tool of learning graphs is going to be introduced to guide the learner through the process of learning in the given scenario. To reach a learning objective, learner will have to "follow the path" of the learning graphs, built up on Smart Learning Atoms, which are certain learning elements that carry defined learning materials.

To ensure barrier free integration in the market, MaTHiSiS makes use of a range of interaction devices, such as specialized robots, mobile devices and interactive whiteboards. The consortium ensures easy-to-use solution with e.g. specialized graphical editor-like tool, allowing to easily create educational materials as well as the reusability within both mainstream education and vocational training setups.

Objectives of the project

A Cloud-based Learner's Space (CLS) will be developed to provide a system for adaptation/personalization in learning, interaction, data acquisition and analysis as well as content creation on the fly. This is a core component of the MaTHiSiS system which includes 3 crucial subsystems which create an innovative smart learning ecosystem: i) the experience engine (EE), a graph-based interactive storytelling engine, that manipulates interactive content that is later sent to a device of tutor's/learner's choice; ii) the learning graph engine, responsible for adaptation of the Learning Graph based on learner's behaviour and interaction; iii) the Decision Support System (DSS) providing and collecting learning analytics and controlling synchronous and asynchronous interaction between devices. To ensure constant educational flow and augmented learner engagement, the emotion recognition and context aware cognitive/behavioural status extraction tools are introduced within the system addressed by the Sensorial Component (SC).

For the purpose of validating MaTHiSiS approaches in learning environment, a set of Smart Learning Atoms (SLA) is going to be created for defined use cases. Such SLAs will adapt to each learner in a different way based on her/his particular needs, profile, cognitive affective state, relevance to specific learning requirements and previous performance. Further, an editor-like tool is introduced to be able to transform educational material into MaTHiSiS Learning Materials usable by SLAs through Learning Actions (LAs). The learning graphs then are going to be deployed to interact with the CLS as well as some front-end tools for tutors and caregivers to enable creation, editing and authoring of the learning contents and learning experiences.

MaTHiSiS will support learning across a variety of learning contexts and, with the use of a variety of devices (robots, interactive whiteboards, mobile devices and desktop/laptop computers), with personalized and adaptable, time and location independent learning paths, being transferred between the agents, always taking into consideration best knowledge and practices learnt from the previous device.

By the end of the project, MaTHiSiS will introduce a marketable innovation, aimed at the re-usability of educational and training content and fostering the interactivity between technology and learners/tutors/caregivers.

Executive Summary

The set of MaTHiSiS platform agents includes mobile devices (smartphones and tablets) on which this deliverable focuses. The first version of the mobile layer was described in "D5.4 Description of the Mobile Layer" [9] and the relevant software code was delivered for its integration in the MaTHiSiS Platform and for its testing in the pilots.

This deliverable provides technical details about the implementation of (the revised architecture of) the mobile layer and about the native Learning Materials (native mobile apps) on Android operated devices. Its aim is to serve as a common reference point among MaTHiSiS software development teams, MaTHiSiS integration team and pilot partners.

In more detail, in this deliverable, we first describe the implementation of the architecture of the platform agents described in chapter 3 of "D5.2 Description of robotic layer" [12] on mobile devices which present specific intricacies. These include the facts that a) the sensing devices existing in the mobile devices and exploited in MaTHiSiS include the gyroscope and the accelerometer; b) due to the limited computing resources available in the mobile devices, the data gathered from the sensors are not processed on the mobile PA but delivered to the MaTHiSiS cloud which undertakes the processing. The architecture of the Platform Agents was changed (as described in more detail in D5.2) after the pilot trials to rectify several drawbacks of the overall system with emphasis on the fast communication between the PAs and the MaTHiSiS cloud components and the homogenization of the MaTHiSiS interface towards the PAs. The introduced modifications targeted both the Experiencing Service modules and the Sensorial Component.

This deliverable also presents additional native Learning Materials that were developed after D5.4 submission to support all MaTHiSiS use cases (the native LMs developed until D5.4 supported a sub-set of MaTHiSiS use cases). Additionally, modifications in the native LMs that were validated in the pilots have been implemented and are reported in this deliverable. These modifications aim to improve the level of satisfaction of the MaTHiSiS users.

1. Introduction

1.1 Document purpose and context

This document contains the revisions of the specifications of the MaTHiSiS mobile layer initially presented in D5.4 delivered in December 2016. This deliverable is produced under task 5.2 "Mobile Layer" and reports on the outcomes of the activities of this task with details of the mobile agents supporting the interactions with the MaTHiSiS system. The revised design of the mobile layer has been based on D2.4 [2] and on the results of the first round of pilots that took place in the first six months of 2017. This is necessary to ensure that all PAs will be interoperable with MaTHiSiS (Cloud-based Learner's Space), all PAs (Platform Agents) can be used in synchronous and asynchronous collaboration scenarios and learning materials can be accessed through multiple PA types. These common requirements have led to the revised definition of certain common functionalities which are described in the Annex of D5.2 [3] (specific reference is made in each chapter of the current deliverable).

The specifications presented in this document refer to all the components that are required so that MaTHiSiS platform runs on mobile devices (smart phones and tablets) towards offering enhanced learning experiences to all types of learners. MaTHiSiS platform includes several Platform Agents (PAs) which will be involved in the learning process. All these share certain common functionalities which are described in D5.2 (the revised version of D5.1) and each of them has its own characteristics and capabilities. This deliverable aims at shedding light to the revision made to all components relevant to the mobile devices. It is worth stressing that a) mobile devices (smartphones and tablets) are widely used by learners of all ages and thus, they consist an important means for MaTHiSiS wide penetration and b) mobile devices can deliver to the learner either web-based content (which can also be delivered through laptop or windows operated IWBs) or through native mobile apps, bringing an additional challenge in learning material delivery and playful learning experience.

The focus here is on Android and on elaborating on the functionality that will allow the testing of MaTHiSiS system already in M22 in the second round of pilots. As such, this report is accompanied by software (relevant code exists in the gitlab repository of MaTHiSiS) which is integrated in the MaTHiSiS platform under "WP7 System Integration" in "D7.3 MaTHiSiS platform, 2nd release" and will be delivered to "WP8 Pilots in Education" and WP9 "Pilots in industrial training and career guidance" for pilot testing.

The description of the components implementing synchronous and asynchronous collaboration is left for the next version of the deliverable as the relevant work will be completed in October 2017 and delivered for trials immediately. We have scheduled regular updates of the mobile layer development based on the outcomes of the pilot testing which will be delivered as "D5.6 Description of mobile layer" in September 2018 respectively. As this is the second (out of the three) releases, the structure of the document is similar and each section focuses on the differences from the previous version.

1.2 Document structure

This document consists of the following chapters:

Chapter 2: Mobile layer requirements. It focuses on additional requirements revealed by the user stories defined after D2.2 [1] and other requirements that were revealed during the first pilots reported in the deliverables of WP8 and WP9.

Chapter 3: The architecture of the MaTHiSiS mobile application(s) with emphasis on the description of the implementation in the mobile devices as the overall Platform Agent architecture is described in D5.2.

Chapter 4: The mobile device abilities. This chapter focuses on the use of sensor readings for affect detection as well as on other mobile devices oriented functionalities.

Chapter 5: The Learning Action Materialization capabilities and the implementation of the LMF (Learning Materialization Framework) which focuses on the revisions requested by the users during the pilots and on additional learning materials created in the 2nd year of the project. The Mobile devices can deliver web-based Learning Materials and native mobile-app based materials. The web-based LMs (Learning Martial) are reported in D5.2.

2. Mobile layer requirements

2.1 Updated User Stories

To comply with the requirements and expectation of the stakeholders and end user, a set of user stories was defined by the whole consortium considering comments, feedback and proposals from groups from different fields of knowledge such as technical and pedagogical partners, learners physiologists, tutors or caregivers. Among the stories defined based on D2.2, the ones which involve (directly or indirectly) the robotic layer are included in Table 2 where the MoSCow classification and the Use Case (UC) that generated it is also mentioned.

We additionally stress that:

- With respect to user story PA59 described as "As a teacher, I want to have a system that will run on equipment available in the class in order to be usable on the older PCs we have available", we have decided that the MaTHiSiS system supports Android devices running android 5 and above. Any device running lower android operating systems will not enjoy the full functionality (e.g. sensor readings).

Code	User Story	MoSCoW	Component	UC	Comments
PA16	As a teacher, I want to be able to manipulate the location of PA's in order to not exclude those who have mobility restrictions such as being bedridden and or aid frame dependant.	M	PA mobile/ tablet	PMLD	ES mobile should be able to function independently without the need to have ES Desktop or looking at the desktop/laptop´s camera. Probably during assisted this will remain for data training purposes. ES mobile will be autonomous, no need to have in parallel ES desktop.
GEN09	As a teacher, I want to have a system that runs on operating systems such as Android, iOS, Windows Phone and as a desktop application in order to allow me to use it in many more situations and within the constraints of my school's equipment.	C	ES Desktop, mobile	PMLD	
GEN20	As a teacher, I want to be able to use the software in a noisy environment (both for inputs and for outputs) in order to prevent me from having to disrupt the class in order to use the software.	M	ES Desktop, mobile	ASD	
GEN19	As a teacher, I want to have been equipped with the operating systems and equipment required for the system in order to ensure that the school is not excluded from MaTHiSiS as the school equipment might not be adequate.	M	ES Desktop, mobile	ASD	
GEN35	As a teacher, I want to be able to run the software without need for extra staff in order to facilitate a possible lack of additional staff resource.	M	ES Desktop, mobile	ME	

Table 2: User Stories relevant to mobile devices

Apart from the user stories relevant to all PAs, the following user stories affect the development taking place in task 5.2 as they related to the learning material development. The same table structure is followed in this table as well.

Code	User Story	MoSCoW	Component	UC	Comments
DSS04	As a teacher, I want to be able to adapt the size of presented text in order to not exclude those with limitation in vision or visual impairments.	S	Frontend, LMs	PMLD	For visual impairements no metadata on the LM. Magellan can be used for this. The Learner profile will be passed when launching the LM at the beginning of the session by the ES.
DSS11	As a teacher, I want to have a system that presents information using both the auditory and visual channel in order to not exclude those who have either a visual or an auditory or motor or verbal impairment or a combination of.	M	LMs	ASD	EE already compares global disabilities with LM metadata and will be further extended with more global params
LMR06	As a teacher, I want to have the ability to present other languages in order to include students without the classes' native language as a first language or to provide means for teaching language.	S	LM translations	ASD	Native mobile LMs that support multiple languages have already been developed. Learning material content translation is out of scope of MaTHiSiS.
PA99	As a teacher, I want to select between Greek and English languages in order to support native as well as immigrant trainees.	M	EE, LMs	CG	For LM translation, see above. For platform translation, it is provided in multiple languages already in the project lifetime.
DSS08	As a learner, I want to be able to use text or images to access content in order to understand and interact with the materials.	M	Web based, native LMs	PMLD	Like DSS11
LMR12	As a learner, I want to be able to use the system based on visual information only in order to overcome my hearing impairment.	S	Web based, native LMs	ME	Like DSS11
PA92	As a learner, I want to use mainly tablets and PCs to provide training in order to be best adapted to the SME where the pilot will be organized.	M	Web based and native LMs	IT	
LMR18	As a learner, I want to have audio and video of the system to be loud and clear in most environments in order to use the	M	LMs	ME	

Code	User Story	MoSCoW	Component	UC	Comments
	system in most reasonable places.				
LES39	As a learner, I want to use my native language in order to understand and interact with the materials.	M	LM translations	ME	
LMR21	As a teacher, I want to have a system that can adapt the tasks using purely audio alternatives in order to support and not exclude those with sensory disability.		EE	IT	Like DSS11
LMR22	As a teacher, I want to have a system that can adapt the tasks using purely visual alternatives for individual users in order to support and not exclude those with sensory disability.		IPA, DSS, LMs	IT	Like DSS11

Table 3: User stories relevant to Learning Materials

Another user story that is relevant to all PAs is the following:

Code	User Story	MoSCoW	Component	UC	Comments
GEN61	As a teacher, I want to be able to join a user community and communicate with other users in order to answer the main technical problems encountered with the solutions they found.	S	SN	ME	Connect account to facebook personal account and be able to post something on facebook account. Be able to post on Social Networks for help let´s say, from an LM in async collaboration

Table 4: User stories relevant to all PAs

2.2 Feedback from driver pilots

The first MaTHiSiS system prototype was delivered to users for validation and testing. The results of the trials are reported in five deliverables, namely D8.1 [4], D8.4 [5], D8.7 [6], D9.1 [7] and D9.4 [8]. Teachers and learners accepted very well the use of mobile devices for learning purposes and as such devices were available in many setting, they were tested in almost all the cases. The comments/results that relate to task 5.2 developments are primarily provided by teachers and concern mainly the design of the learning materials while for the execution of a learning process loop the main comment was that they needed technical assistance. Both facts come as no surprise as in the driver pilots, there was no time to train the involved actors in the use of the system based on user friendly documentation and tutorials and as the focus in the first year was not on the accurate design of the learning materials but on the development of the most innovative components of the system and their integration. In any case, we list here the main comments which are now taken into account in the revision of existing and design of new learning materials. The comments are:

- Implement some reward mechanism in the learning materials.
- Offer learning material with multiple levels of difficulty.
- Develop learning materials where the selection of icons/images is used in the evolution of the learning process instead of having to write sentences to make them more suitable for use case targeting people with disabilities.
- The option to provide additional attempts for answer should be supported (When a student gets an answer wrong they should always be given another opportunity to answer. Ideally a parameter in the system could define the number of opportunities that students should be given.
- The inclusion of sound or music in the activities to aid in keeping students' attention and making pictures larger, especially for those who are visually impaired has been also proposed.

Several discussions arisen on the accessibility issues emerging from the driver pilots. Although the broad support on accessibility features is provided by the PAs itself (e.g. color inversion), the need to adapt certain content within the learning material respecting certain disabilities of the learner was of crucial importance. The challenge has been posed to address this requirement given the screen limitations of mobile devices. More details on addressing the feedback and a framework of the development are described in Chapter 5.

3. The architecture

3.1 Experiencing Service

The Experiencing Service Mobile Client is the mobile application which incorporates the User Interface for mobile agents, the connectivity handler, the sensorial component and the LM launcher as shown in Figure 1. The User Interface for mobile agents consists of the "settings Activity", the "login Activity", the "welcome activity" and the "ready activity" components.
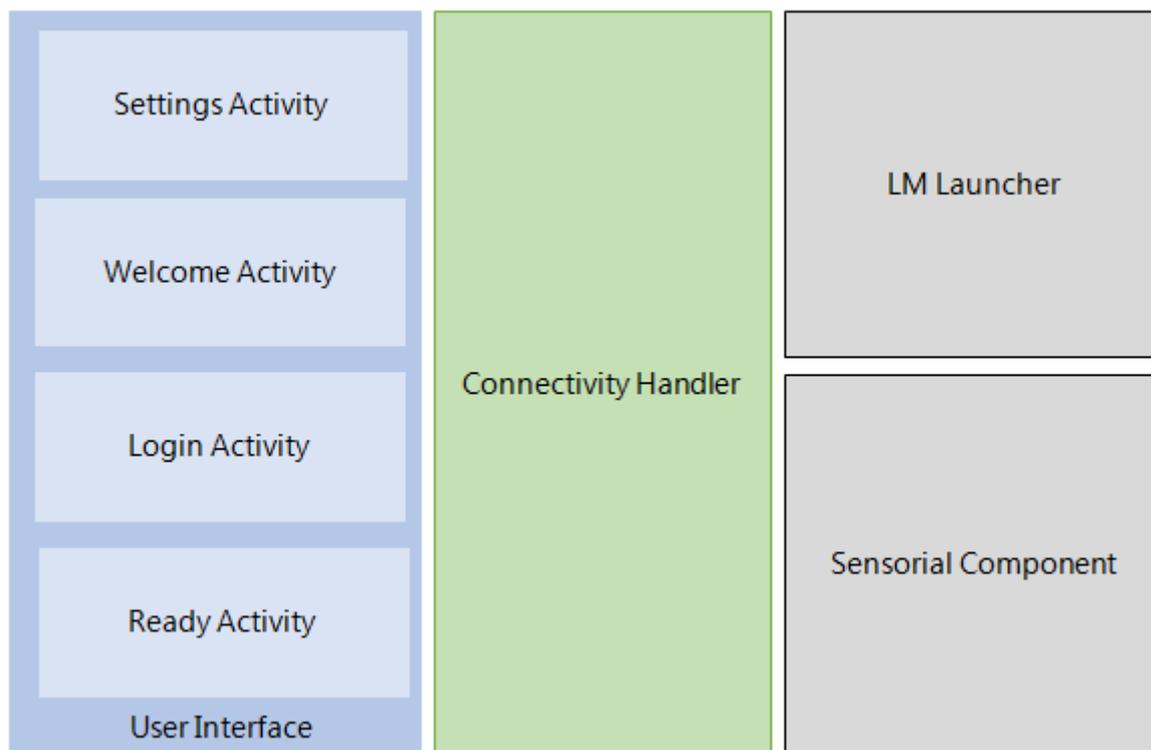
Figure 1: Mobile Application Architecture

3.1.1 User Interface and Connectivity Handler

The ES Mobile Client should provide a user interface in order to enrich the user experience and to ensure the data flow which is described in BP1 "Learning Experience". The screens that the user can interact with are:

- **Login Page:** The user should be authenticated by the MaTHiSiS platform. When the user tries to enter the MaTHiSiS ES Mobile Client, a login form appears on the screen. The user is able to enter their credentials (username/password). When she/he fills them, the Login controller send them through a secure web socket channel to the ES Server to ensure that the user has the permission to enter the platform and secondly to let the MaTHiSiS cloud platform know about the user who uses the specific device.
- **Welcome Page:** After a successful login process, the user can access the main functionality of the application. The welcome page, informs the user about the current technical status of the system. This happens in order to let the user know about potential connectivity issues or the required actions that the user should do. Also, from this page, the user is able to set the required parameters in order to be connected to the MaTHiSiS cloud platform. These parameters are the Platform Agent name, the Sensorial Component Name and the Learning Environment that the user is located.

- **Ready Page:** It is mandatory to set the parameters in the welcome page. These parameters are checked from the internal algorithm and if they are correct, the user can access the ready page. The ready page was developed for two reasons. Firstly, to inform the user about the settings they have selected. Secondly, from this page the user can declare that from now on the current device is ready to start a learning experience.
- **Connectivity Handler:** In parallel with the user flow, the connectivity handler is a background service which is responsible of informing the cloud service about selected parameters and settings .These values simplify the user flow and to enrich the user experience. Thanks to the connectivity handler component, the user learns instantly if the connectivity with the cloud is established (or not); the user can use the same device with the same settings without entering them again. Also, the connectivity handler is the main orchestrator of the functionality which will be executed in each step.

3.1.2 Sensorial component tier

The sensorial component is implemented in the mobile devices as a background service. This service collects the gyroscope and the accelerometer values and delivers them to the MaTHiSiS cloud (through the ES Server). The sensorial component starts to read values from the inertia sensors when a Learning Material is launched to the user screen. These measurements are stored locally in the device until the ES Server asks for them. Then, the Sensorial Component sends the measurements in a specific and predefined structure to the ES Server.

The sensors that MaTHiSiS uses are the gyroscope and the accelerometer. These sensors provide a set of measurements (X,Y,Z) using a concrete sample frequency. When the SC asks for values, the available (stored) data is sent every time the sensorial component asks for these values.

For the Learning Materials which are Web-Based, ES Client for Mobile provides a web-view area in which the Learning Material is executed. That means that there is an ability to use the 2D touch screen sensor. More specifically, for Web-Based Learning Materials, the Sensorial component records the user interactions – the points the user taps (X,Y) and the action the user does (touchdown, touchup, drag start, drag stop). These measurements enrich the data set that is sent to the ES Server, in order to achieve a more accurate affect state detection.

The Sensorial Component is in close communication with the main background service orchestrator (Connectivity Handler) of the ES Client, and collects the sensors raw data until the connectivity handler notifies the Sensorial Component to stop gathering data. The raw data contains values from the sensors but also each data set is accompanied with a timestamp. This timestamp is used in order to synchronize data from different platform agents among them. Since different devices can have different time settings, MaTHiSiS cloud platform provides a way to have synchronized data between different devices. That is achieved using a 3rd independent endpoint which returns the current timestamp which constitutes the reference point. Hence, each data set is in full sync with the global (MaTHiSiS platform) clock.

3.1.3 The Learning Action Materialization tier

The Learning Action Materialisation tier defined in D2.3 is implemented by the LM launcher component. The LM launcher is another background service running on the mobile devices. It is orchestrated by the communication handler.

When the communication handler service receives the command to start a Learning Material from the ES Server, apart from starting the Sensorial Component, it is responsible to inform LM launcher about the new Learning Material which must be started. The LM launcher receives the specific command and tries to start the Learning Material.

The LM launcher supports web-views. In the case that the Learning Material is a web-based LM, it is required to be executed in a web browser – or in a headless browser (web browser without GUI) depending on what the LM launcher provides. The LM launcher combines the information that receives from the communication handler and (except from starting the LM) it is responsible to send this edited information (information related to the learning session and the learner) to the Learning Material. The Learning Material uses this information in the xAPI statements [10] .

In the case that the Learning Material is a native application, the LM launcher tries to find it in the already installed applications in the device. If the application does not exist, the LM launcher informs the user about the required actions (for example the location from where to download the required application). Otherwise, the LM launcher launches the application (the learning material) and it sends the required information for the xAPI statements as well.

4. Mobile layer-specific abilities

The mobile devices offer a variety of features that can be used in the learning process and experience. They are equipped with a variety of sensors that can be used by the learning materials to enrich the learning experience or to enable/improve the affect state detection. Also, they offer the ability to execute OS-independent (web based) learning materials into their screens exploiting the advantages the internet offers. Most important of all, most of the users are familiar with the usage of a mobile device (either it is a smartphone or a tablet). Apart from the experiencing services which support both dependent and independent learners, the mobile devices offer access to the LES, URM and PC functionalities.

4.1 Description

While the sensors available on the mobile devices are numerous (touchscreen, camera, microphone, speakers, accelerometer, gravity sensors, gyroscopes, rotational vector sensors, Ambient light / temperature sensor), it was decided to track the readings of the gyroscope, accelerometer and 2D touch sensors as this delivers information that can be used to detect the user's affect state (according to "WP4 Affective and Natural Interaction Instruments" for affect state detection and "WP6 Collaboration and Decision Support System" for adaptation of the LGs).

It is worth stressing that while reading the gyroscope and accelerometer is possible throughout the user experience irrespective of the type of the learning material used, the situation is different when the user-learner interacts with a native mobile app. In this case, the native mobile application is in the foreground while in the background runs the sensorial component. For security reasons, the operating system does not allow the background service to access the readings of the touch screen sensor while in the foreground an application different from the MaTHiSiS main application runs.

With respect to the 2D sensor, the available readings are:

- Touch down(is triggered when the user presses their finger on the screen - the X and Y point of the touch and the event duration)
- Touch up (is triggered when the user releases their finger of the screen - the X and Y point of the touch and the event duration)
- Touch move (is triggered when the user move their finger on the screen - the X and Y point of the touch and the event duration)

4.2 Main abilities implemented

4.2.1 LES, URM and PC accessed through the mobile devices

To satisfy the requirement to support administrator, independent learners, tutors and caregivers through the mobile devices, we have designed a dedicated mobile application which allows all these types of users to connect to the MaTHiSiS system. This mobile application allows them to access MaTHiSiS front-end which has been designed and developed in task "3.5 MaTHiSiS Front End", as shown in the following figures (Figure 2 and Figure 3). As the reader can download the applications on their mobile device (from the MaTHiSiS gitlab) and obtain own-experience, the figures show representative screens only as evidence that the mobile apps have been developed.
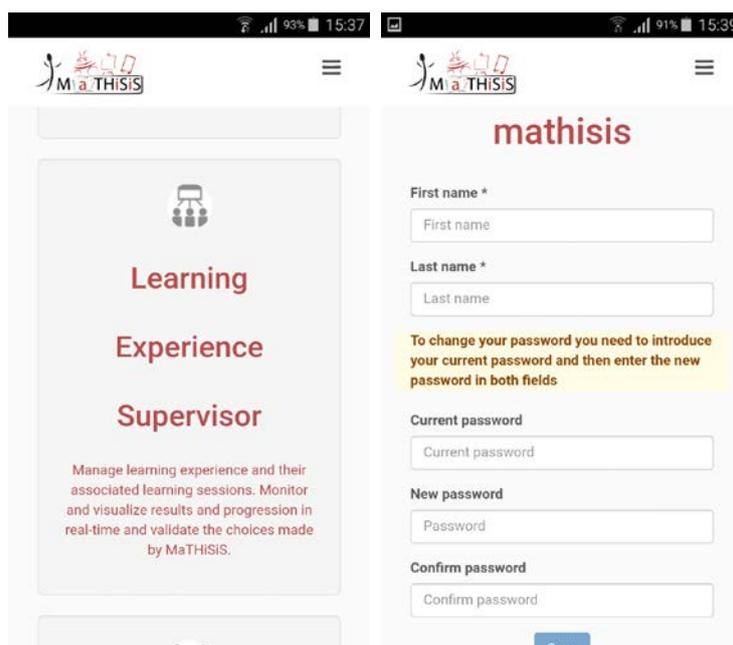
Figure 2: MaTHiSiS front-end accessed through mobile devices

Through this, the tutors, care-givers, independent learners and administrators will have access to the learning experience supervisor, user and role manager and platform configuration components.

4.2.2   User Interface Enrichments

To improve the user experience, the ES Mobile Client has been enriched with some configuration options as it is described in section 3.1.1. The mobile application offers the ability to the user to set the platform agent name they prefer, the sensorial component name and the venue they are in. Also, the "ready" screen has been added in which the user on the one hand can see the total configuration of the client – to ensure that they have correctly setup the device. On the other hand, the user can see the whole communication with the MaTHiSiS cloud from an area offered in the ready screen which records logs in a user-friendly way. It is totally developed to inform the user in a transparent way about the potential connectivity issues they may face.

a) Login Activity screen	b) Welcome Activity screen
c) Settings activity screen	d) Ready Activity Screen
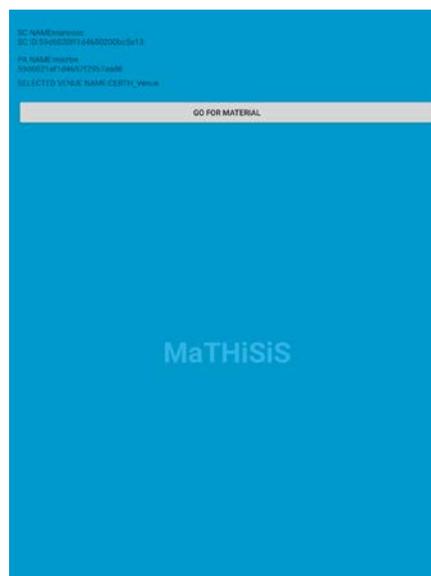
Figure 3: MaTHiSiS front-end: example screens from the different User Interface components

4.2.3 Local Database Storage

During the communication with the ES Server, the selected platform agent and the selected sensorial component (for the mobile layer case the sensorial component is hosted in the same device with the PA) are getting specific ids to have a stable communication with the cloud. These ids in this mobile application version are stored in a local (MySQL) database. Hence, the user is not obliged to deal with non-human-friendly strings (as the ids are) and she/he is not obliged to declare them in each learning session (as was the case in the previous versions).

5. Learning Action Materialization capabilities in the mobile devices

Through the mobile devices, MaTHiSiS users can interact with two types of LMs: native LMs (which in the case of the mobile device these are native mobile apps) and web-based LMs which can be of any type (e.g. pdf, html5, mp4). All LMs send information to MaTHiSiS cloud in xAPI statement format regarding the interactions of the learner and the material. This information includes primarily data regarding the performance of the learner such as success rate and time to complete the interactions. The basis for the development is the list of learning materials defined in D2.2 together with the key moments specified per learning material.

This chapter provides some of the examples of created LMs that reflect several types of the activities the learner can perform when interacting with them. It is worth to mention that **in total 54 native LMs** for mobile PAs were developed with **3 difficulty levels each**. In order to support assisted pilots an array of different LMs are available to the pilot users in a number of variations that are in line with the requirements, suitable to the use-case, age group and type of disability. The following description of LMs is just an indicative example, whereas the full list can be seen in Annex 3 of this deliverable.

In this deliverable, we also present the first LM that has been defined and developed to support the case of synchronous collaboration. While synchronous collaboration is the focus of task "6.3 Synchronous collaboration among platform agents" and the relevant efforts are reported in "WP6 Collaboration and Decision Support System" deliverables, we include here the description of the collaborative LM as LMs are developed only in "WP5 Platform Agents".

5.1 LM framework for native apps

The Native LMs for the mobile devices are native mobile apps for Android and iOS devices which communicate with the MaTHiSiS cloud to receive instructions and report back technical issues and xAPI statements revealing the performance of the learner. Numerous materials have been produced to support the driver pilots as well as the forthcoming assisted pilots covering many scenarios across all the use cases. The platform agent support accessibility features on the OS level (both in Android and iOS) that can be activated through the general settings of a mobile device offering several features like Increased contrast, Inversion of the colors and so on. Nevertheless, creation of the accessible learning material or any other mobile application requires the involvement beyond the development team and including the design and QA teams. For this a number of guidelines and best practices have been followed offering more inclusive and versatile experience therefore increasing the LMs reach and reusability. Thus, a decision on the font types were towards a use of 'Roboto' font face, which has a mechanical skeleton, wider and rounder form, which gives a greater clarity and an optimistic look, settled into its natural width offering a more natural reading rhythm that is more commonly found in humanist and serif types[1]. It is highly optimized and widely used as a default font on Android operating system as well as all the Google services.

Further, all mobile LMs offer the possibility to change the font size within the learning material following major guidelines and best practices on accessibility[2,3].Thus, a separate functional button introduced gives the user the possibility to choose between normal, medium and large fonts.

5.1.1 xAPI Statements in Native applications:
Native applications are following the Tin Can (xAPI) specification mapping the interactions of the user with the learning material to capture the information related to the learner's state that is further

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[1]https://fonts.google.com/specimen/Roboto
[2] https://w3c.github.io/low-vision-a11y-tf/requirements.html#text-size
[3] http://mashable.com/2011/04/20/design-for-visually-impaired/#KOMQQBfHdPql

going to be analyzed in the cloud of the platform. The example of the statement sent from a native mobile LM is provided below. Note that the structure stays similar across several of the LMs with the difference being mainly in interactions and statements within a given LM (e.g. initialization, passing, mastering or failing an interaction, passing or failing a question, terminations etc.)

```
{
      Json::Value Actor(Json::objectValue);
      Actor["name"] = "";
      Actor["type"] = "";
      Actor["mbox"] = "";

      Return Actor;
}
{
      Json::Value Verb(Json::objectValue);
      Verb["id"] = "";
      Verb["display"]=[];
      Verb["display"]["en-US"] = "";

      Return Verb;
}
{
      Json::Value Object(Json::objectValue);
      Object["definition"] = [];
      Object["definition"]["name"]=[];
      Object["definition"]["name"]["en-US"]="";
      Object["id"]="";
      Object["activity type"]="";

      Return Object;
}
{
      Json::Value Result(Json::objectValue);
      Result["completion"] = "";
      Result["success"]="";
      Result["time-needed"]="";
      Result["score"]=[];
      Result["score"]["scaled"]="";
      Result["score"]["min"]="";
      Result["score"]["max"]="";

      Return Result;
}
{
      Json::Value Context(Json::objectValue);
      Context["location"] = "";
      Context["learner_id"]="";
      Context["session_id"]="";
      Context["key_moment"]="";

      Return Context;
}
char timestamp[] = "";
```

5.1.2 Native apps: Name the object

This particular learning material was extracted from the Mainstream Education Case (MEC) and is reusable in a number of other use cases with a slight variation of interaction but the logic stays the same aiming towards achieving the learning goal of enriching vocabulary and object recognition. The following LM prompts the user to name the object that is depicted on the screen and provides

instructions to the learner to fill in the word describing the picture. Further variations offer the selection of the appropriate picture among those that are proposed that matches the words on the screen. The native mobile game notifies the MaTHiSiS cloud (IPA) through xAPI statement about the correct or wrong answer and the time it took to complete the tasks (key moments).
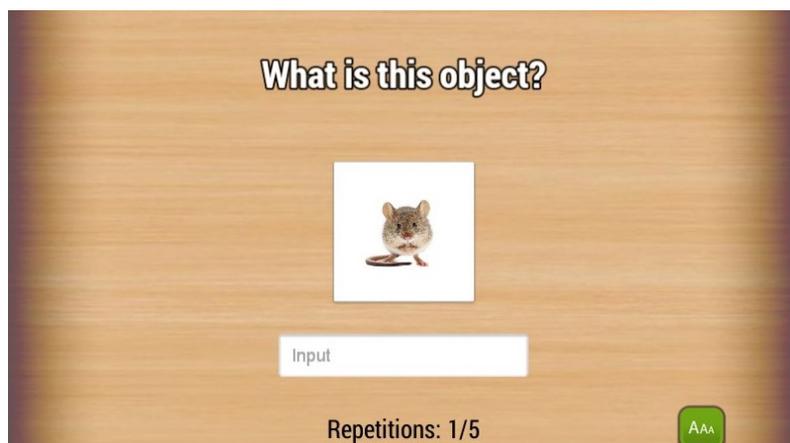
Figure 4: Example of LM - native mobile app developed for the Mainstream Education use case

5.1.3   Native apps: Pairs

Further type of common LM across several use cases has a learning goal to improve memory of the learner. Here, a set of cards are shown to the learner while they must turn them over one by one finding the pairs with same images. Ultimately this LM as many others are provided in three difficulty levels: Easy level - 10 cards are shown, Medium level: 15 cards, Hard level: 20 cards. Through the xAPI the LM sends to the cloud the results of the interactions: score and the number of correct guesses.
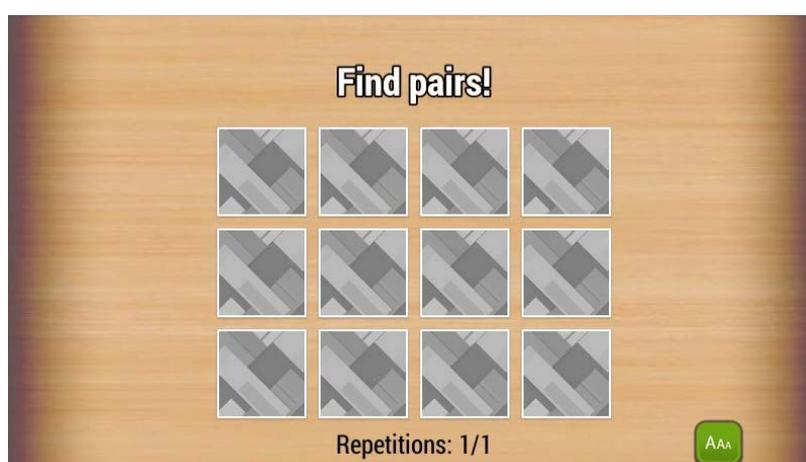
Figure 5: **Pairs LM screenshot for Mobile PA**

5.1.4   Native apps: Piano

The following learning material addresses a group of learning goals for developing Motor Skills and Memory. The LM presents the learner a sequence of interactions on the piano keys and the goal of the game is for the learner to repeat the sequence playing a melody. The game starts with the challenge pressing one key at a time gradually increasing the number of keys to repeat based on the difficulty at which the game is played. The LM sends the result of the interaction whether it was failed, passed or mastered.
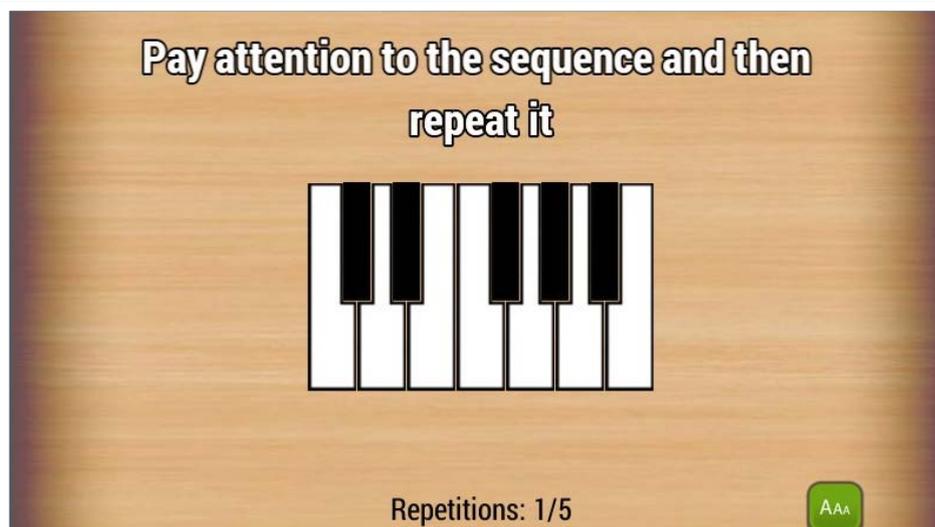
Figure 6: **Piano LM screenshot for Mobile PA**

5.1.5 Native apps: Labyrinth

In the use cases of PMLD with or without physical disabilities as well as ASD, the labyrinth game helps to develop hand-eye coordination. The game levels are based on the difficulty of the labyrinths the learner must navigate through adding more complex turns. In easy level the learner must navigate through 2 labyrinths using navigation buttons on the screen, in medium level- 4 labyrinths and in hard level - 8 labyrinths. The learners aim is to move a "monster" along the obstacles/walls of the labyrinth and make the monster eat the cookie placed at the exit of it. The xAPI sends the interaction result on learner's success and the time taken.

Figure 7: **Labyrinth LM screenshot for Mobile PA**

5.1.6 Native apps: Largest or smallest number.

To develop Mathematical skills of the learner, based on the requirements, different versions of size/number comparison LMs were proposed (other version prompts to pick the object according to its size). The LM displays a set of numbers whereas the learner has to identify the largest of the shown numbers. Following the same logic as in the other LMs, this one constitutes of three difficulty levels differentiating between the numbers themselves and the cards offered on the screen (e.g. from 4 cards in easy level to 6 cards in hard). The key moments envision the initialisation, accomplishment and failure statements.
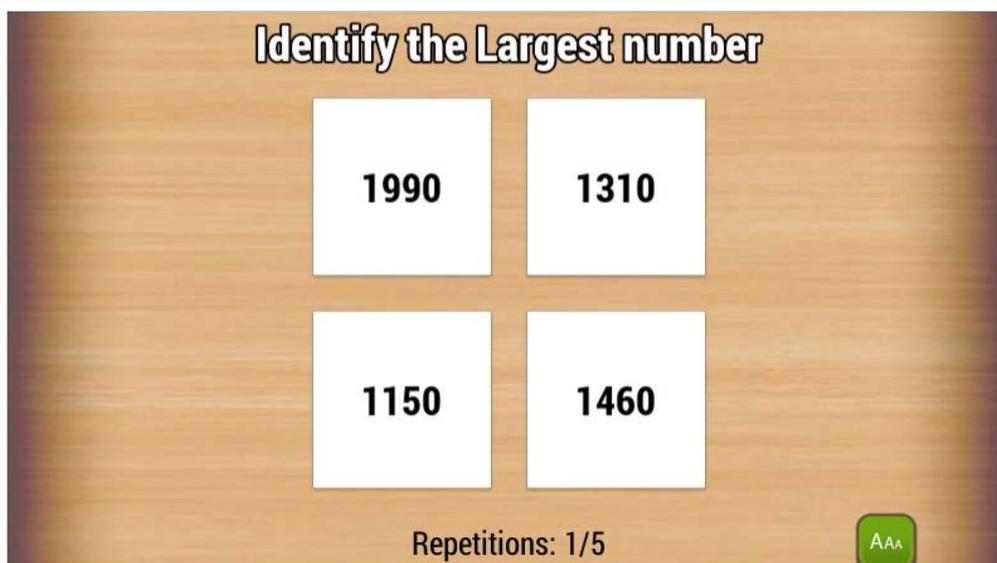
Figure 8: **Identify the Largest Number LM screenshot for Mobile PA**

5.1.7 Native apps: Order the Numbers

Used in MEC, ASD and PMLD use cases, an Order the Numbers LM is designed for the learning goal of developing Mathematical Skills. The LM presents the learner with a set of numbers on top of the screen whereas they must put them in an ascending order by dragging them into the boxes at the bottom of the screen. The set numbers offered to the learner to choose from increases with each difficulty level from 3 to 20 for hard level. Same logic was applied in a number of other LMs offering grouping the objects by colours or shapes, grouping objects by sizes, etc.
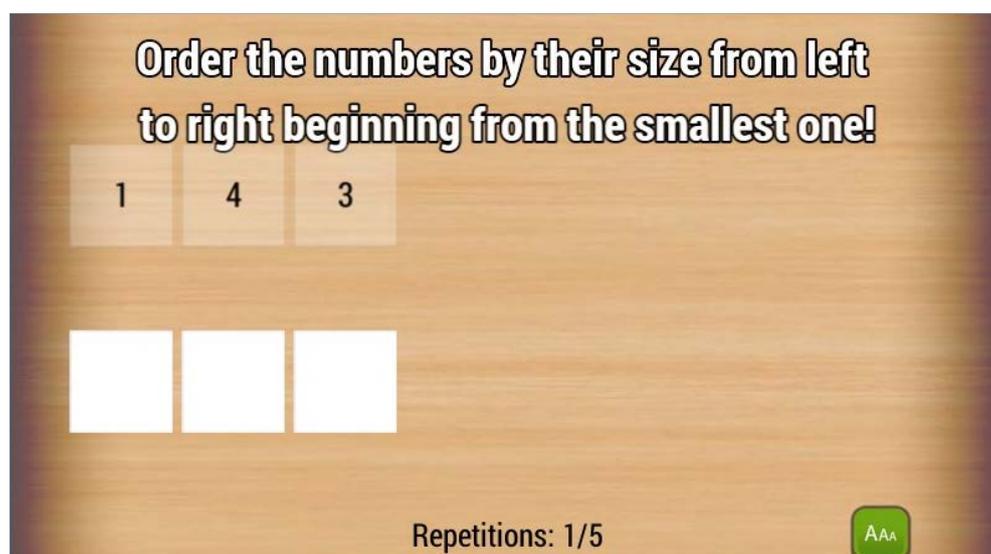
Figure 9: Order the Numbers LM screenshot for Mobile PA

5.2 LM framework for web-based materials supporting synchronous collaboration

In the period from the delivery of D5.4 till now (September 2017), a large number of web-based materials have been developed to support the MaTHiSiS pilots. As web-based LMs are primarily reported in chapter 5 of D5.8 [11] here we focus on the web-based LM that was developed to support the synchronous collaboration scenario, which follows the same architectural/technological directions (e.g. with respect to the type of communication with the CLS) but with certain

modifications to support the interactions of the learner. For example, with respect to the tracking of the interactions, here the "key moments" notion is extended to also express the "help" provided by a learner to another as well as to trigger "help". Further details on the synchronous collaboration scenarios and implementation will be provided in D6.4 [13].

5.2.1   Example of collaborative LM: "Short the numbers"

This learning material is developed for the "JCYL_ME" learning graph, associated with the "maths skills" learning goal, smart learning atom: Number Quantity correspondence and learning action: associate a number with a quantity.

This Learning Material assumes the interaction between two learners, situated in different classrooms using tablets or one using tablet and another using a computer. Emphasis is on collaboration therefore a home screen that emphasises this is a team effort and not a competition between two "players" is required. The names of the players/learners appear on the screen as well as the levels of the games or how many games the team has completed. The evolution of the learning material is described in the following sequence of steps:

1. Both learners switch on and the LM starts at the easiest level: For both learners, the screen displays four empty slots/boxes at the top of the screen and four numbers at the bottom of the screen.
2. For each learner, only two of these numbers can be interacted with. Their communication is indicated on the screen.
3. They are instructed on the rules of the game. Rules are that they have two numbers and their partner has another two numbers. The four numbers have to be dragged to the boxes above so that the smallest comes first and the biggest last. However, they have to do this with their partner who has the other two numbers.
4. System randomly selects one learner (Learner 1) to start and first box on left (the one that should take the smallest number) flashes or lights up.
5. Learner 1 is asked "which is the smallest number?" "Is it yours or your friend's?" "If it is yours drag it to the box that is flashing". If it is correct, it will stay in the box, if not, it will move back to the boxes below. Ina more advanced level, if it is wrong it could just stay there and learner 2 could have the option to move it or learner 2 could click on learner 1's numbers as shown in their own device which would make it flash (one learner prompting another) on both screens but only learner 1 could move it.
6. Then the turn passes to learner 2. Then learner 2 is asked "which is the lowest number ./which number goes next?" If it is theirs, she/he can drag it into the box. If correct it stays there, if not, it will return to the boxes below and learner 1 will then have the opportunity to either move their own number or highlight learner 2's number.
7. Each time a correct number will be in its cell at top of the screen there is auditory and visual rewards.
8. Game is over when all four numbers from the bottom of the screen are in the boxes above.

For a collaborative game, the two learners may well come into the game with various levels of competency. Their level at the end could be calculated separately by taking into account their individual performance and how much help they had from or gave help to their partner. If both learners have similar affect profiles at the end of the game, next presentation of collaborative material could be the same for both. The alternative scenario is that one ends the game in a different affect state, see Table 5. We assume here that if a learner is bored, it is because the level is too easy for him, so the bored learner should be prompted to help the other one. This is assuming that helping someone who is less competent than you will be engaging.

		Learner 2		
		Bored	**Frustrated**	**Engaged**
Learner 1	**Bored**	OK		
	Frustrated	Bored player must help the other learner	OK	
	Engaged	Bored player must help the other learner	Engaged player must help the other learner	OK

Table 5: Adaptation in cooperative learning scenarios

Regarding the levels of difficulty, three levels are supported:

- Easy level: 2 numbers
- Medium level: 3 numbers
- Hard level: 4 numbers

The range of numbers per level is:

- Easy and Medium: 100-10.000
- Hard level: 100-1.000.000

5.2.2 Quantification of the help

A prominent issue in the synchronous collaboration scenarios is the quantification of the help provided by one learner to another and how this is taken into account to adapt the learning experience. While the latter is addressed in WP6, the quantification of help affects the development of the learning material as it also implies the key moments that have to be traced.

Initially, help would be defined as all the occasions when one learner take the option to take the other learner's turn or highlight the other learner's correct response remotely on their screen. This would then just result in a frequency of "help interactions" (number of helping interactions per unit of time). In order to obtain these parameters, the xAPI statements will provide the needed information. The synchronous scenarios to be considered in MaTHiSiS (as part of task 6.3) will implement a tracking of specific interactions, in the line of the set of xAPI statements defined to perform the affect understanding through interactions with the learning material in task 4.2.

The initial set of events which will be tracked are (using the Tin Can standard – *Actor + Verb + Object*):

- Learner asked learner: one learner asked for help to another learner
- Learner answered learner: one learner takes the option to take the other learner's turn
- Learner responded learner/interaction: this statement could be used, for example, to indicate that a leaner has provided some information about his/her affective state (using emoji's, specific buttons, etc.)
- Learner helped learner: one learner highlighted the other learner's correct response remotely (on their screens)
- Learner filled in the correct box in XX seconds.
- Learner succeeded in his move (successful filling of one box in the LM mentioned in the annex).

This set must be expanded in order to cover as many relevant events as possible. Moreover, these statements can be enriched using the optional elements (such as "Results" or "Context") to provide

more useful information about the context of the interactions. We can define parameters that can describe the kind of collaboration experiences in previous interaction. These parameters should represent concepts such as:

- Collaboration with learners from a higher level (this learner is more comfortable in a scenario where he/she is helped)
- Collaboration with learners from a lower level (this learner is willing to help other peers)
- Collaboration with learners from the same level (this learner is comfortable interacting in a collaborative scenario but they prefer not to ask or be asked several times)
- The learner doesn't enjoy the experience in collaborative learning.

Further refinements with respect to the quantification of help and its exploitation to adapt the learning experience will come in the last deliverable of this task after having collected feedback during the assisted pilots.

The key moments are associated with the correct/wrong filling of the number, the completion of the game and the provisioning of help.

6. Conclusion

The feedback received through the driver pilots has led to modifications in the PA architecture (detailed in D5.2 [12]) which affect the implementation of the mobile layer and in modifications in mobile-specific functionalities like the sensorial components and the native LMs. The mobile specific modifications and the native LMs have been described in this document in technical detail. The modification included the insertion of a user interface (GUI), the implementation of the updated Business Process 1 description (including a web socket client-server interaction) and the implementation of additional native LMs as well as modifications of existing ones. The updated version of the relevant code exists in the gitlab (the links for all the code will be provided in D7.3). The software has been integrated in the platform and is ready to be used in the assisted pilots. This includes apart from the Experiencing Service client, **54 native LMs** for mobile PAs with each of them supporting 3 difficulty levels and a **web-based LM for** suitable for **synchronous collaboration** scenarios.

The Experiencing Service client for the mobile device has already been integrated in the MaTHiSiS platform, which will be used in the MaTHiSiS assisted pilots. During the pilot trials, feedback from the end users (teachers and learners) will be collected in WP8 and 9 and this will be dispatched back to the technical WPs (including WP5). Based on the feedback that we will collect, we will decide potential improvements towards improved user satisfaction. As such the next steps include:

- The improvement/development of additional learning materials for collaborative scenarios.
- The development of the Experiencing Service and native LMs in iOS depending on the pilot user interest.
- Improvements in currently available deployments.

All these steps will be reported in the next version of the deliverable "D5.6 Description of the mobile layer" that will be available in September 2018.

7. References

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[2] Alexandre AHMAD, D2.4 Full System Architecture Deliverable of the MATHISIS project, 2017.

[3] Hortal Enrique, "D5.2Description of the robotic layer", Deliverable of the MATHISIS project, 2017.

[4] D8.1 Report on Autism Spectrum Case pilots, Deliverable of the MATHISIS project, 2017

[5] D8.4 Report on Profound and Multiple Learning Disabilities Case pilots, Deliverable of the MATHISIS project, 2017

[6] D8.7 Report on Mainstream Education Case pilots, Deliverable of the MATHISIS project, 2017

[7] D9.1 Report on Industrial Training pilots, Deliverable of the MATHISIS project, 2017

[8] D9.4 Report on Career Guidance Distance Learning pilots, Deliverable of the MATHISIS project, 2017

[9] D5.4, Description of the mobile layer, Deliverable of the MATHISIS project, 2017

[10] D4.3, Affect Understanding in MaTHiSiS, Deliverable of the MATHISIS project, 2017

[11] D5.8, Description of the Interactive Whiteboard Layer, Deliverable of the MATHISIS project, 2017

[12] D5.2, Description of the Robotic Layer, Deliverable of the MATHISIS project, 2017

[13] D6.4, Synchronous and Asynchronous collaboration among platform agents, Deliverable of the MATHISIS project, 2017

8. Annex

8.1 Information about xAPI

Information about the xAPI is provided in [10].

8.2 General description of the Experiencing Service

The General description of the Experiencing Service is provided in chapter 3 of D5.2 [12].

8.3 List of learning materials suitable to be accessed through mobile device in MaTHiSiS use cases

	SLA	Learning Actions	PA	Materialization
PMLD — **SLA Worked examples (LG: Improve vocabulary)**	**Object identification (LG: Improve vocabulary)**	Name colours / objects / actions when presented	Tablet	Display a series of single images on a theme.
				Give feedback and prompting (if no response, prompt twice, then change object)
	Quantity correspondence (LG: Improve maths)	Associate a number with a quantity	Tablet	Display a number of dots.
				Give feedback and prompting (if no response, ask, "Are there [random number]?", if no response twice, change number, if response is hesitant, offer 3 alternatives)
	Sequence reproduction (LG: Improve attention span)	Reproduce a sequence of pictures/sounds	Tablet	Display a number of images on screen. Highlight two in sequence.
				Increase number of items highlighted by one each repetition.
				Give feedback and prompting (repeat if response is wrong, or no response.
				Reduce number in sequence if no response twice)
LG: Increase vocabulary	**Visual attention**	Visually track pictures (focusing)	Tablet	It will present different pictures about one topic (functional vocabulary). They move in the screen.
		Looking at pictures for a time.	Tablet	It will present different pictures about one topic (functional vocabulary). They will be static in the screen.
	Hearing attention	Focusing a sound of words.	Tablet	It will present different sounds of words: ☐ Pupil´s interests toys.

					☐ Foods. ☐ Animals. ☐ Clothing. ☐ Body parts.
			Hearing a sound of different words for a time.	Tablet	It will present different sounds of different words: ☐ Pupil´s interests toys. ☐ Foods. ☐ Animals. ☐ Clothing. ☐ Body parts.
		Visual discrimination	Find differences between two words.	Tablet	It shows different words from different vocabulary. They can be support with photographs, pictures, images, icons, symbols.
			Match two identical words between a set of them.	Tablet	It shows several words from one set about one topic. It could be support with photographs, pictures, images, icons, symbols.
					The pupil should match the identical words.
		Establish semantic fields (conceptual networks)	To connect words about one semantic field.	Tablet	Create screens with different topics (home, school, park, swimming pool, hospital). Then the pupil has to add elements (things, people, decoration…).
		Use derived words form	To connect derived words about one topic.	Tablet	In the screen there is one word about a topic (e.g. bread). Then in the screen appear a set of words, only one of them will be linked with the first word.
					Pupil has to match the word which has the same lexical family (e.g. bread-baker-bakery).
					All words can be supported by images or pictures.
					Difficult on the task can be increased with more words.

LG: Identify and express emotions (emotional traits)	**Visual attention**	Visually track pictures (focusing)	Tablet	It will present different pictures about one topic (emotional traits). They move in the screen.	
		Looking at pictures for a time.	Tablet	It will present different pictures about one topic (emotional traits). They will be static in the screen.	
	Hearing attention	Focusing a sound.	Tablet	It will present different sounds about one topic: emotional traits ☐ Crying. ☐ Laughs. ☐ Snarls.	
		Hearing a sound for a time.	Tablet	It will present different sounds about emotional traits during a time.	
	Visual discrimination	Find differences between two facial expressions.	Tablet	It shows different facial expression from pictures of children (photograph, picture, image, icon, symbol).	
				Differences increase.	
		Match two identical pictures.	Tablet	It shows several facial expressions from pictures of children (photograph, picture, image, icon, symbol).	
				The pupil should match the identical pictures.	
	Make eye contact	Make eye contact with different facial expression.	Tablet	A simulator of facial expression makes different emotional traits while pupil makes eye-contact.	
	Imitation	To imitate facial expressions.	Tablet	A simulator of facial expression makes different emotional traits while pupil imitates them.	
	To know parts of the face	Lotus games with part of the face (eyes, noses, cheek…)	Tablet	Pupil matches pictures with the same part of the face, between several cards that shows parts of the face.	
				The cards are face down.	
		Making puzzles with faces forms.	Tablet	Pupil completes a puzzle with the different parts of the face.	
				The number of puzzle pieces will increase according to pupil's progress.	

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D		**To know parts of the body**	Lotus games with part of the body (leg, arms…)	Tablet	Pupil matches pictures with the same part of the body (between several cards which one shows parts of the body?)
					Cards should be face down.
		Know basic emotions	Say emotions.	Tablet	It shows different pictures (photograph, image, icon, symbol) and pupil says what emotion they express.
			Classify emotions.	Tablet	It shows different pictures (photograph, image, icon, symbol) at the same time and the pupil says what emotion they express.
		Deduce basic emotions	Deduce basic emotions from different social situations.	Tablet	It shows different stories about different social situations (sequences) and pupil says what emotion they express.
		Express basic emotions	Virtual role playing (children without movement possibilities)	Tablet	It shows a virtual role-play and pupil will express an emotional trait.
			"Emociómetro"	Tablet	It asks to pupil – How are you? How do you feel today?
					And pupil has to respond
	LG: Telling the time from analogue clock	**Learning numbers 1 to 12 (this SLA also contributes to mathematics learning objectives)**	Correctly identifying numbers by matching them to numbers of objects	Mobile	Would need simple game/procedure written eg presenting three pictures and three numbers and learner has to drag them around to match them.
			Getting them in ascending order	Mobile	Would need simple game/procedure written e.g. presenting series (starting with two, then increasing) of cards depicting different size groups, then cards displaying the digits. For each set of cards, pupil has to drag them into place with smaller followed by larger
		Learning position of numbers on clock face	Copying clock with just 4 numbers in place	Mobile	think a drag and drop game could address this one
			Copying clock with all 12 numbers in place	Mobile	Ditto

		Recognising hour hand and learning its role	Learns at what time activities take place eg start and finish school	Mobile	Learner drags correct clock face over to where the question is written. Text will convert to speech when it is touched by learner.
			Places hour hand in correct place in response to verbal prompts e.g. "one o'clock"	Mobile	Learner drags hour hand round tom position given in text/spoken instruction.
		Recognising minute hand and learning its role	Learns concept of half past the hour and position of hour and minute hand	Mobile	Clock face with both hands and all 12 numbers. Learner moves hands around until they hit e.g. half past six and voice message says what time it is. Then learner has to move hands or select correct clock face depending on what time (e.g. half past four) they are told.
			learns concept of quarter to/past and position of hour and minute hand	Mobile	Clock face with both hands and all 12 numbers. Learner moves hands around until they hit e.g. quarter past six and voice message says what time it is. Then learner has to move hands or select correct clock face depending on what time (e.g. quarter to four) they are told.
			learns concept of five minute intervals and position of hour and minute hand	Mobile	Same activities as above but examples will involve moving the minute hand round to one of the twelve numbers
	LG: Rehearse travel, get things in right order and learn to find way around school	**Understand left and right (could be a learning objective in its own right?). As an SLA contributes to other learning objectives.**	Learning which shoe/hand/foot is left and which right (this will only apply to the learner's point of view as understanding that a robot or person facing them has a reversed left and right is pretty difficult).	Mobile	Again, this would be left and right from learner's point of view. Shown series of two identical objects side by side and asked to touch the one on the right or the one on the left.
			Recognise left and right arrows	Mobile	Arrow shown on screen. Learner has to respond as above in the robot scenario and also to a mannequin shown on screen/IWB
			understand turning left and right	Mobile	Move character round 2D maze with simple commands or tapping arrow on screen. Maze can become more complex

		Identify and name (or recognise symbol for) different places/rooms	Match name or symbol to different rooms	Mobile	Matching game either shown symbol and has to select correct picture from those below or shown all symbols and has to pair each one with correct location picture
			Identify location of different places on map/model	Mobile	Learner has to drag pictures/symbols onto correct location of 2D representation of school.
		Walk/navigate to find location		Mobile	Desired location shown on screen. Learner then has to move character to desired location from their current location.
	LG: Sequencing	**Sorting objects into right order, (this SLA can contribute to building sentences if verbal/written material used).**	Learn sorting	Mobile	One object appears on top of screen and learner must drag it into one of two or three baskets shown at bottom of screen according to colour or shape.
			sorting on increasing value on one dimension e.g. height, number in group	Mobile	One object appears on top of screen and learner must drag it into correct position at bottom of screen depending on whether it is bigger or smaller than its neighbour. Could also be number of dots. Increase number of cards/objects as learner gets better at task.
			On two dimensions eg size and shape	Mobile	One object appears on top of screen and learner must drag it into correct position on matrix.
		Understanding order of events or actions	Sort pictures into logical order eg child waking up, dressing, eating breakfast, leaving house. Identify incorrect sequences	Mobile	Learner drags pictures from top of screen into correct order at bottom
			Tell story or recount an event/outing in right order supplemented with their own pictures	Mobile	Learner tells story and selects pictures from those shown on device
			Sort words in sentence into logical order. Identify incorrect order.	Mobile	Learner drags pictures from top of screen into correct order at bottom

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		Sort places on route into logical order (use their own pics taken on outing). Identify incorrect order.	Mobile	Learner drags pictures from top of screen into correct order at bottom
		Get right order for elements in Chris' game making software or Scratch commands	Mobile	Ditto: can Mo help here?
LG: Increasing vocabulary	**Correct recognition of objects**	Correctly points to picture of object named by tutor, being given an increasing number of objects to choose	Mobile	Word said by device and learner selects named object from display on screen
		Matches written name to picture being given an increasing number of objects to choose from	Mobile	Matching game, either shown word and has to select correct picture from those below or shown all words and has to pair each one with correct picture. If verbal, has to say each word as it is matched.
		Plays Fish or pairs game	Mobile	Learner has to select the two cards showing the same picture from a display of 10 or more. To make it more challenging cards shown face down and have to be turned over. Alternatively match word cards with pictures.
	Correct recognition of action words	Correctly points to picture of action named by tutor, being given an increasing number of actions to choose	Mobile	Matching game either shown written word (or spoken word) and has to select correct picture from those below or shown all words and has to pair each one with correct location picture.
		Plays Fish or pairs game	Mobile	Learner has to select the two cards showing the same action picture from a display of 10 or more. To make it more challenging cards shown face down and have to be turned over. Alternatively match word cards with pictures.
	Correct recognition of descriptor	Correctly points to picture of descriptor (eg big, yellow, hairy) named by tutor, being given an increasing number of descriptors to choose	Mobile	Matching game either shown written word (or spoken word) and has to select correct picture from those below or shown all words and has to pair each one with correct picture

		words			
			Plays Fish or pairs game	Mobile	Learner has to select the two cards showing the same descriptor picture from a display of 10 or more. To make it more challenging cards shown face down and have to be turned over. Alternatively match word cards with pictures. .
		Improving pronunciation	Correctly responds with name of object/action/colour when shown it.	Mobile	Picture shown on screen and learner has to respond with correct pronunciation then gets score as reward.
	LG: Building sentences	Identifying different classes of words	Sorting selection of pictures into groups	Mobile	Sorting pictures from top of screen into three baskets below.
			Correctly identifying class of picture by putting into correct pile	Mobile	One picture at a time appears at top of screen and learner has to drag them in correct basket at bottom.
		Pairing object and descriptor words	Sorting objects into groups, then into groups according to colour or size	Mobile	One object appears on top of screen and learner must drag it into correct position on matrix.
			Identifying on two dimensions.	Mobile	Several pictures from 2D sorting tasks above shown on screen. Tutor asks eg "Show me the black cow" and learner has to touch correct picture.
			Correctly describing presented object and its descriptor (for verbal learners).	Mobile	As above but pictures of object shown on screen and learner has to give correct description.
			Pairs /Fish game pairing object with appropriate descriptor words	Mobile	Object presented at top of screen. Learner has to select the two words that accurately describe it from a selection of 10 or more below. To make it more challenging, words only revealed when "cards" clicked.
		Pairing object and action	Sorting objects into groups, then into groups according to action (eg "running rabbit"	Mobile	Either pictures presented one at a time at top of screen and learner has to drag them to correct basket or all pictures shown at top at same time before first sorting. Then second

words					sorting is into correct action "basket".
			"Show me the children who are playing"	Mobile	Tutor asks question and learner has to select correct card from at least 10 on screen showing e.g. children either sitting, playing, running, standing or cows jumping, running, lying down etc.
			Correctly describing presented object and its action	Mobile	As above but pictures of object shown on screen and learner has to give correct description.
			Pairs /Fish game pairing object with actions it could make	Mobile	Pictures presented at top of screen. Learner has to select the two words that accurately describe it from a selection of 10 or more below. To make it more challenging, words only revealed when "cards" clicked.
		Linking object-action-object	Correctly describing picture "What does Sara hit?" "What is the boy doing to the trolley?" or identifying correct symbol	Mobile	Picture shown on screen and tutor asks question.
			Using three picture cards to create meaningful object action object sentences	Mobile	Tutor says e.g. "the dog chases the cat" and learner has to select three pictures from several shown at top of screen and drag them below in the right order.
			Using three word cards to create meaningful object-action-object sentences	Mobile	Tutor says e.g. "the dog chases the cat" and learner has to select three words from several shown at top of screen and drag them below in the right order.
			Correctly verbalising object-action-object picture	Mobile	Picture shown at top of screen learner has to say the three words in the right order. Alternatively could read out words

					shown in previous exercise.
ASD	LG: Identify and express emotions (emotional traits)	Visual attention	Visually track pictures (focusing)	Tablet	It will present different pictures about one topic (emotional traits). Pictures move in the screen.
			Looking at pictures for a time.	Tablet	It will present different pictures about one topic (emotional traits). They will be static in the screen.
		Hearing attention	Focusing a sound.	Tablet	It will present different sounds about one topic: emotional traits ☐ Crying. ☐ Laughing. ☐ Snarling.
			Hearing a sound for a time.	Tablet	It will present different sounds about emotional traits during a time.
		Visual discrimination	Find differences between two facial expressions.	Tablet	It shows different facial expression- it will be using pictures of children (photograph, picture, image, icon, symbol).
			Match two identical pictures.	Tablet	It shows several facial expressions from pictures of children (photograph, picture, image, icon, symbol).
					The pupil should match identical pictures.
		Make eye contact	Make eye contact with different facial expression.	Tablet	A simulator of facial expression makes different emotional traits while the pupil makes eye contact.
		Imitation	Imitate facial expressions.	Tablet	A simulator of facial expression makes different emotional traits while the pupil imitates them.

To know parts of the face	Lotus games with part of the face (eyes, nose, cheek...)	Tablet	Pupil matches pictures with the same part of the face, between several cards that shows parts of the face.	
			The cards are face down.	
	Making puzzles with faces forms.	Tablet	Pupil completes a puzzle with the different parts of the face.	
			The puzzle pieces will increase according to pupil progress.	
To know parts of the body	Lotus games with part of the body (leg, arms...)	Tablet	Pupil matches pictures with the same part of the body, between several cards that show parts of the body.	
			The cards are face down.	
Know basic emotions	Say emotions.	Tablet	It shows different pictures (photograph, image, icon, symbol) and the pupil says what emotion they express.	
	Classify emotions.	Tablet	It shows different pictures (photograph, image, icon, symbol) at the same time and the pupil says what emotion they express.	
Deduce basic emotions	Deduce basic emotions from different social situations.	Tablet	It shows different stories about the social situations (sequences) and the pupil says what emotion they express.	
Express basic emotions	Virtual role playing (children without movement possibilities)	Tablet	It shows virtual role-play and the pupil will express an emotional trait.	
	"Emociómetro"	Tablet	It asks to pupil – How are you? How do you feel today?	
			And the pupil has to respond	

Mainstream / **LG: Improve the spontaneity of language**		**Imitation**	Imitate gestures in a song/story.	Tablet	It will tell a story/or sing a song. The story/song will have a different gesture with the body. The child will imitate them.
			Imitate onomatopoeia in a song/story.	Tablet	It will tell a story/or sing a song that will include different onomatopoeias.
					Pupil will have to imitate them.
		Make questions spontaneity	Guess where is one object/person.	Tablet	Hide an object/person (which it can be the robot) and the pupil will ask to clues to guess what it is.
					Robot greet pupil and ask him something to start the game with clues.
		Describe	Describe a picture.	Tablet	The screen shows an image/picture.
					Robot says the beginning of the sentence: for example, "the ball is…"
					and pupil has to complete the sentence "…red!".
	SLA Worked examples	**Sequencing (sorting)**	Sort cards into logical order.	Tablet	Put cards into correct sequence for zebra crossing.
		Simple flow control	Develop a simple flowchart.	Tablet	System plays a video of a zebra crossing.
					Student puts cards into correct sequence for zebra crossing.
					System plays a tutorial (video) of adding a start symbol, linking it to an output symbol with an arrow to turn lights on and off.
					Student creates flow chart.
		Flow control	Develop a mimic flowchart.	Tablet	System describes flow chart symbols.
					System plays a Zebra crossing video.
					Student creates a flow chart to mimic the Zebra crossing.

LG: Develop mathematical competences: numbering	**Subitizing and counting**	Counting a set of objects.	Tablet	In the screen appear a set of objects and pupil will have to count them suddenly (at first sight).
	Associating number to an amount	To make relations with numbers and a set of picture.	Tablet	In the screen appear a set of objects and numbers. The pupil match the set of pictures with the correct number.
	Discrimination of greater than / less than	Put the numbers in order (rising/descending)	Tablet	In the screen there are numbers in a random order.
LG: Increase vocabulary	**Visual attention**	Visually track pictures (focusing)	Tablet	It will present different pictures about one topic (functional vocabulary). They move in the screen.
		Looking at pictures for a time.	Tablet	It will present different pictures about one topic (functional vocabulary). They will be static in the screen.
	Hearing attention	Focusing a sound of words.	Tablet	It will present different sounds of words: ☐ Pupil´s interests toys. ☐ Foods. ☐ Animals. ☐ Clothing. ☐ Body parts.
		Hearing a sound of different words for a time.	Tablet	It will present different sounds of different words: ☐ Pupil´s interests toys. ☐ Foods. ☐ Animals. ☐ Clothing. ☐ Body parts.
	Visual	Find differences between two words.	Tablet	It shows different words from different vocabulary. They

		discrimination			can be support with photographs, pictures, images, icons, symbols.
			Match two identical words between a set of them.	Tablet	It shows several words from one set about one topic. It could be support with photographs, pictures, images, icons, symbols.
					The pupil should match the identical words.
		Establish semantic fields (conceptual networks)	To connect words about one semantic field.	Tablet	Create screens with different topics (home, school, park, swimming pool, hospital). Then, the pupil has to add elements (things, people, decoration…).
		Use derived words form	To connect derived words about one topic.	Tablet	On the screen, there is one word about a topic (e.g. "bread"). Then, a set of words appear on the screen, only one of them is connected with the first word.
					The pupil has to match the word, from the same lexical family (e.g. "bread"-"baker"-"bakery").
					All the words can be supported by images or pictures.
					Difficult levels can be increased using more than just one word.
CGDL	**Worked example: (LG: Prepare for the labour market)**	**Create an e-career portfolio**	Watch a tutorial video of EOPPEP about an e-career portfolio	Tablet, Smart phone	Agent presents a tutorial video to the client/ learner according to his/her age". EOPPEP e-portfolios for adolescents http://www.eoppep.gr/teens/index.php/digital-folder and for adults http://e-stadiodromia.eoppep.gr/index.php/e-portfolio.html
			Complete a questionnaire to assess whether the learner is capable to determine which are the main elements to be considered in his/her portfolio		Agents show to the client 2 questionnaires. First a multiple choice query and then another one with only 2 questions right or wrong answer. When he fills the queries the cognitive state is updated.

			Ask learner to create an initial draft of his/her portfolio and sent it to his/her Career Guidance counsellor		Agent presents to the learner the application of EOPPEP to create his e-portfolio. http://www.eoppep.gr/teens/index.php/digital-folder and for adults http://e-stadiodromia.eoppep.gr/index.php/e-p
			Session to discuss his created portfolio with his/her Career Guidance counsellor. The counsellor will assess whether the draft is complete and which elements need more attention		Agent invites the learner to a session with his counsellor to discuss his created portfolio
		Draft a CV	Watch a tutorial video of EOPPEP about CV drafting	Tablet	Agent presents a tutorial video to the client/ learner according to his/her age".
			Complete a questionnaire to assess whether the learner is capable to determine which are the main elements to be considered in his/her CV		Agents show to the client 2 questionnaires. First a multiple-choice query and then another one with only 2 questions right or wrong answer. When he fills the queries the cognitive state is updated.
			Ask learner to create an initial draft of his/her CV and sent it to his/her Career Guidance counsellor	Tablet, Smart phone	Agent presents to the learner the application of EOPPEP to create his CV (https://europass.cedefop.europa.eu/el/documents/curriculum-vitae)
			Session to discuss his created CV with his/her Career Guidance counsellor. The counsellor will assess whether the draft is complete and which elements need more attention		Agent invites the learner to a session with his counsellor to discuss his CV
		Prepare for a job interview	Watch a tutorial video of EOPPEP about job interview	Tablet, Smart phone	Agent presents a tutorial video to the client/ learner according to his/her age".
			Complete a questionnaire to assess whether the learner is capable to determine which are the main elements to be considered in a job interview		Agents show to the client 2 questionnaires. First a multiple-choice query and then another one with only 2 questions right or wrong answer. When he fills the queries the cognitive state is updated.
Worked example:	**identify the**		client watches video tutorial about self-awareness key factors (to be created within MATHISIS)	Tablet, Smart	Agent presents a tutorial video to the client/ learner according to his/her age".

(LG: Self-awareness)	**importance of personal traits, career values and interests in career planning**	Complete a questionnaire to assess whether the learner is capable to determine which are the main elements of self-awareness	phone	Agents show to the client 2 questionnaires. First a multiple-choice query and then another one with only 2 questions right or wrong answer. When he fills the queries the cognitive state is updated.
Worked examples (LG: Career management)	**knowledge of labour market**	client watches video tutorial about EOPPEP videos of professions http://www.eoppep.gr/teens/index.php?option=com_videos&view=playvideo&Itemid=740&videoid=1	Tablet, Smart phone	Agent present to the client/ learner EOPPEP videos of professions http://www.eoppep.gr/teens/index.php?option=com_videos&view=playvideo&Itemid=740&videoid=1
		Complete a questionnaire to assess whether the learner is capable to determine which are the main characteristics of a profession		Agents show to the client 2 questionnaires. First a multiple-choice query and then another one with only 2 questions right or wrong answer. When he fills the queries the cognitive state is updated.
	career decision making	EOPPEP video about about decision making process (to be created within MATHISIS)		Agent present to the client/ learner an EOPPEP video about decision making
		Complete a questionnaire to assess whether the learner is capable to determine which are the main elements of decision making		Agents show to the client 2 questionnaires. First a multiple-choice query and then another one with only 2 questions right or wrong answer. When he fills the queries the cognitive state is updated.
	Career Management Skills	EOPPEP video about CMS (to be created within MATHISIS)		Agent present to the client/ learner an EOPPEP video about CMS
		Complete a questionnaire to assess whether the learner is capable to determine which are the main elements of CMS		Agents show to the client 2 questionnaires. First a multiple-choice query and then another one with only 2 questions right or wrong answer. When he fills the queries the cognitive state is updated.

Table 6: List of learning materials suitable to be accessed through mobile device in MaTHiSiS use cases