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1. ENHANCE project Overview

ENHANCE – strENgtHening skills and training expertise for TunisiAN and MorocCan transition to industry 4.0 Era – is an Erasmus Plus project founded under the KA2 Cooperation for innovation and the exchange of good practices (Capacity Building in the field of Higher Education) programme by the European Commission under Grant Agreement N° 619130, to be conducted in the period January 2021 until January 2024. It engages 7 partners from 5 countries with a total budget of 779k€. Further information can be found at http://eplus-enhance.eu/.

The emergence of industry 4.0 concepts and applications brings new paradigms impacting all the industrial business domains when they need to conduct successful digital transformations or increase workshops connectivity. The evolution of Maintenance, Production and Quality Engineering (MPQ 4.0) represents the main application domains where Industry 4.0 produces effective beneficial results.

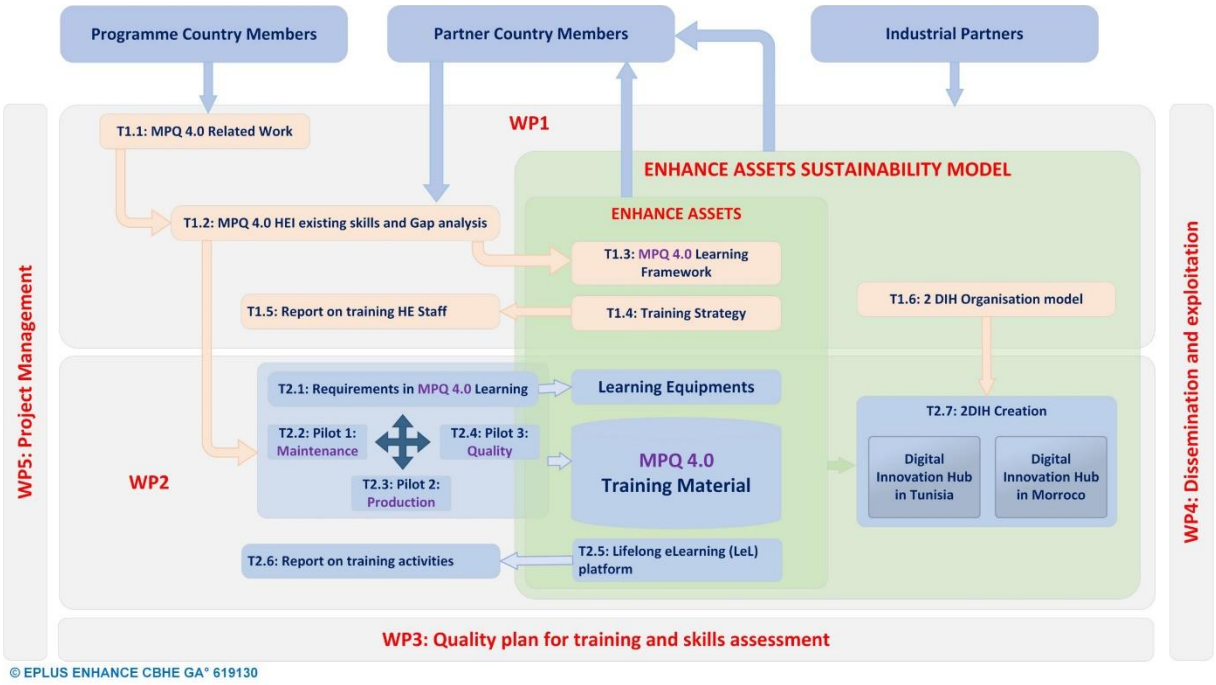

Figure 1 - ENHANCE Project Organisation

The ENHANCE project focuses on building new MPQ training capacities at Higher Education Institutions (HEI) in Tunisia and Morocco to establish interactions between the following stakeholders:

- European universities and research institutions (from France, Germany and Portugal) confirmed MPQ 4.0 competencies, training materials, collaborative research projects, full operational Digital Innovation Hubs (DIH), technology transfer experiences, etc.
- Partner country universities (from Tunisia and Morocco) with teaching and training activities in MPQ and existing connections with their local industrial partners.

The ENHANCE project will create several outputs and two primary tangible outcomes:

- New MPQ 4.0 equipment and training materials developed in connection with the existing training programmes and consolidated through three industrial pilots. The new material will be used to train the trainers and the students in the different partner country universities.
- Two DIHs, one in Tunisia and one in Morocco to sustain the project outcomes through their reuse for training in industry.

ENHANCE aims to become the reference model for creating effective and sustainable training material for MPQ 4.0 in both partner countries with content approved by academia and industry.

2. Introduction

In recent years, the industry in North Africa (also called Maghreb) region, especially Morocco and Tunisia, is facing a historical turning point when considered on a global scale. The digital age comprises a new way of thinking regarding manufacturing and operations. To improve the attractiveness for investment and to meet market requirements of competitivity, in terms of performance, quality, and sustainability, both Morocco and Tunisia need to support industrialization. In this context, this project focus on industry 4.0 and particularly on the three following topics: Production 4.0, Maintenance 4.0 and Quality 4.0, which represent key industrial business processes that particularly need attention, investment and improvement. Through this project, several Tunisian and Moroccan universities and companies showed their interest to develop skills and knowledge to take full advantage of industry 4.0 paradigm and technologies related with these three core business processes of Industry 4.0.

2.1. Purpose of the document

This document presents the tools and technologies to use for the development of the different teaching activities according to LF-MPQ4.0 and addressing challenges related to the three topics of MPQ4.0. More precisely, describe the methodologies used to define the learning equipment that will be bought by HEI partners and used to develop courses and uses cases activities.

2.2. Reference documents

D1.1 - Literature review about required skills related to MPQ4.0

D1.2 - Gap analysis between HEIs and industry 4.0 skills related to MPQ4.0

D1.4 - Design of training strategy for partner HE staff

D1.5 - Report on Train Tunisian and Moroccan HE staff according to the LF-MPQ4.0

2.3. Applicability

The methodologies proposed in this deliverable will help HEI partners to define what equipment are needed to develop the activities they select to enhance their current programs. The objective is to ensure that the selected equipment will be used by a large number of activities selected by each partner.

2.4. Definitions

No particular definitions or concepts are presented in this document.

2.5. Structure of the document

Section 1 – ENHANCE project Overview

Section 2 – Introduction

Section 3 – Learning material selection methodology

Section 4 – Learning equipment selection

Section 5 – Final activity selection for “train of the trainers” sessions

2.6. List of acronyms

HEI - Higher Education Institution
PC – Partner country

3. Learning equipment selection methodology

3.1. General methodology

The selection of equipment will depend on the need of each HEI partners regarding the list of activities that will be selected to enhance the current program. In order to help the HEI partners to define the list of equipment, a selection methodology is adopted to facilitate this step of the project. As presented in figure 2, this methodology is based on the list of technologies requested for MPQ4.0 and that are identified and presented in D1.1 and used in D1.2 to assess current HEI programs and the industrial company efforts with respect to industry 4.0. Simultaneously with the definition of the teaching activities constituting the common courses and uses cases (presented in D1.4 and D1.5), the different possible types of equipment are discussed. Indeed, the identification of the type of technologies will help the HEI partners to select the specific equipment to be used in the different activities. This selection may take several iterations and discussions with internal and external experts. It depends also on the budget allocated for the equipment acquisition. Finally, and with the selection of the activities that will be used for the trainers training sessions and added to the current HEI programs, each HEI partner should define the equipment to use for each activity. This help to justify why each equipment has been selected.

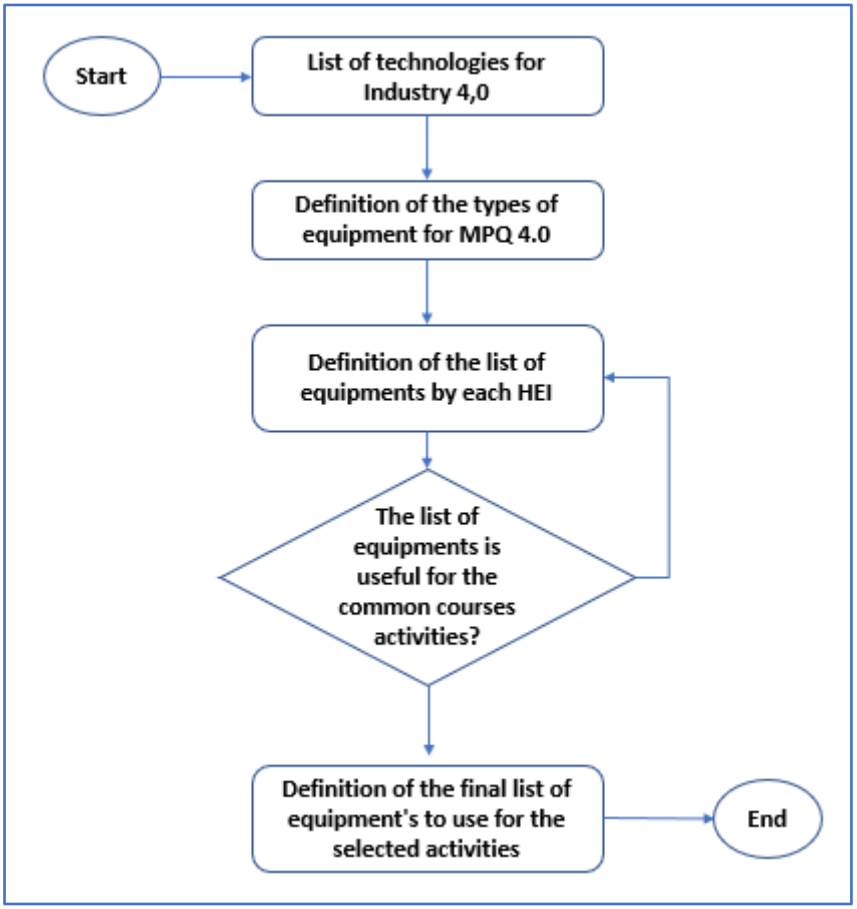

Figure 2 Methodology of learning equipment selection

3.2. Type of equipment's definition based on industry 4.0 technologies and common activities

At the end of task 1.5, a list of activities has been defined to constitute the list of courses and use cases that should be developed during the WP2. The definition of these activities is based on industry 4.0 technologies already presented on D1.1 and used in D1.2 to assess HEI curricula and the industrial company's maturity with respect to industry 4.0. The focus has been mainly on the technologies that may be used for maintenance, production and quality. Table 1 and 2 present the final list of activities that will be used to enhance HEI partner curricula and the list of associated technologies targeted by these activities' definition. The combination activities – technologies lead to define the different types of equipment that may be useful to develop the activities and master MPQ 4.0 related technologies. Figure 3 presents the different types of equipment's that may be considered to develop the activities.

Table 1. Summary of Industry 4.0 enabling technologies.

Technology	Description	Code
Cyber-physical systems	CPS is a collection of transformative technologies that connects the operations of physical assets and computational capabilities. The main aim is to monitor physical systems while creating a virtual copy	1
Internet of things	Information network of physical objects (sensors, machines, cars, buildings, and other items) that enables the collection and exchange of data, allowing interaction and cooperation of these objects	2
Big data and analytics	Collection and analysis of large amount of available data using a series of techniques to filter, capture and report insights, where data are processed in higher volumes, with higher velocities and in greater variety	3
Cloud technology	System for the provision of online storage services for all applications, programmes and data in a virtual server, without requiring any installation	4
Artificial intelligence	System that thinks humanly and rationally according to six main disciplines, including natural language processing, knowledge representation, automated reasoning, machine learning, computer vision and robotics	5
Blockchain	A database that creates a distributed and tamperproof digital ledger of transactions, including timestamps of blocks maintained by every participating node	6
Simulation and modelling	Technologies that mirror the physical world data such as machines, products and humans in a virtual world, aiming for simplification and affordability of the design, creation, testing and live operation of the systems	7
Visualization technology (augmented and virtual reality)	Augmented Reality: a set of innovative Human Computer Interaction (HCI) techniques that can embed virtual objects to coexist and interact in the real environment; Virtual Reality: application of computer technology to create an interactive world, allowing the user to control the virtual object and whole virtual scene in real time	8
Automation and industrial robots	Machinery and equipment that automate operational processes, containing also Collaborative Robotics, which allows humans and machines to operate in a shared learning environment	9

Additive manufacturing	Process of joining materials in successive layers to make objects from 3D model data to 'unlock' design options and achieve great potential for mass-customisation	10

Table 2 List of activities for common courses and uses cases

Course	Ref.	Name
Advanced Maintenance strategies	Act 1.1	Use cases of eXtended Reality (XR) in Smart Maintenance 4.0 contexts
	Act 1.2	Sensor Network Design in Smart Maintenance 4.0 contexts
	Act 1.3	Failure Modes, Effects & Criticality Analysis (FMECA) in Smart Maintenance 4.0 contexts
	Act 1.4	Contributions of Smart Maintenance 4.0 to Energy Management & Energy Efficiency of Industry 4.0 Assets
	Act 1.5	Sustainability Driven Smart Maintenance 4.0
Integrated maintenance planning	Act 2.1	Data-Driven Reliability for Smart Maintenance 4.0
	Act 2.2	Maintenance planning and scheduling in Industry 4.0 contexts
	Act 2.3	Contributions of Industry 4.0 technologies to Total Productive Maintenance
	Act 2.4	Downtime forecast and optimal maintenance planning
	Act 2.5	Industry 4.0 Asset & Maintenance Management Systems
Use case for maintenance	Act U.1.1	Real time communication
	Act U.1.2	Data acquisition and storage in industry 4.0
	Act U.1.3	ML and application for maintenance
	Act U.1.4	Dashboarding, Reporting and data visualization
Production, planning, scheduling and control in industry 4.0	Act 3.1	Design and development of smart Production Planning/Scheduling systems
	Act 3.2	Planning and scheduling techniques and approaches in industry 4.0
	Act 3.3	Methods and framworks for control systems in agile manufacturing
	Act 3.4	Data-driven planning/scheduling models and algorithms
	Act 3.5	Big data and predictive inventory analytics
Factory 4.0: Concepts, techniques, and application	Act 4.1	PLM and Digital Factory
	Act 4.2	VSM for production 4.0
	Act 4.3	Virtual Reality for simulation
	Act 4.4	Dashboarding, Reporting and data visualisation
Use case for production	Act U.2.1	Emerging technologies for production planning and scheduling
	Act U.2.2	Horizontal and vertical integration & Workflow management
	Act U.2.3	CPS design and development
	Act U.2.4	Data driven inventory management
	Act U.2.5	Digital control systems (DCSs)
Advanced PSS Quality Design	Act 5.1	Integrated thinking system modelling and development
	Act 5.2	Non-Conformities RCA and Quality gates design
	Act 5.3	QC model design
	Act 5.4	Design for X applied for Quality

	Act 5.5	IoT and BPM for Integrated VSM
QC analytics for Zero defect manufacturing	Act 6.1	Integrated process improvement
	Act 6.2	Quality Process maturity self-assessment and lifecycle management
	Act 6.3	Inspection Methods, sampling, Inspection Plan
	Act 6.4	Prescriptive and adaptive decision for Quality Control
	Act 6.5	Quality Planning, Control and Management functions
Use case for quality	Act U.3.1	Sensor's sensitivity analysis and selection
	Act U.3.2	Non-Conformities RCA and Quality gates design
	Act U.3.3	IoT and BPM for Integrated VSM
	Act U.3.4	Quality Process maturity self-assessment and lifecycle management
	Act U.3.5	Prescriptive and adaptive decision for Quality Control

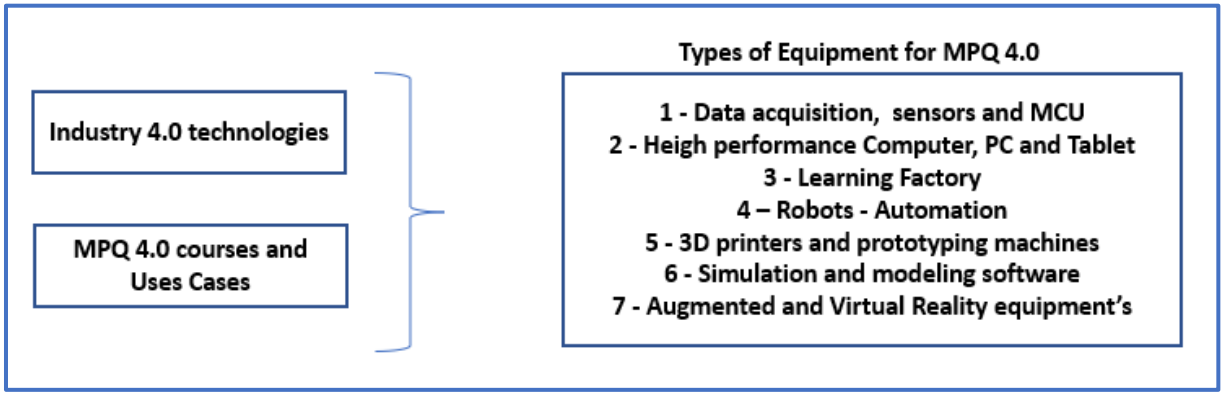

Figure 3 Types of equipment definition

A brief description of the different types of equipment is given in the following:

1. **Data acquisition systems, sensors and microcontroller:** this type represents all components that may be used to collect data from the industrial systems (machines, conveyor, material handling systems, products, workers, …)
2. **Heigh performance Computer, PC and tablet:** this type represents the equipment that may be used for data storage and the execution of artificial intelligence methods. Some equipment will be useful also for the dashboarding and the data visualization.
3. **Learning Factory:** this type of equipment permits to show an example of smart factory that involve several technologies of industry 4.0. It allows students and experts to see what should be used as components and devices for smart industry purpose.
4. **Robots:** It is among the technologies of industry 4.0 recommended to show how a combination of interconnected components and technologies may help to develop industrial systems.
5. **3D printers and prototyping machines:** this type of equipment will be used to improve and validate the product design before fabrication.
6. **Simulation and modelling software:** some software tools are often recommended in the context of industry 4.0 to ensure analysis and process simulation.
7. **Augmented and Virtual Reality equipment's:** this type permits to create an interactive world allowing the control of virtual objects and systems.

Based on these types, the HEI partners were defined the specific equipment to use for the activities. The equipment selection and validation will be discussed in the next session.

4. Learning equipment selection

4.1. Activity - equipment selection engagement

To validate the final list of equipment that will be bought by each HEI partner, the equipment utility should be appropriate to the list of activities selected by each partner to enhance the current programs. An overall list of specific equipment has been firstly defined with the help of EU partners. The role of EU partners is important at this level to add specific equipment according to the need and vision of different PC partners. After that, each partner should select, for each activity, the equipment that may be used. Finally, each partner should define the final list of activities that will be consumed in trainers training sessions and used to enhance the current programs. The list of equipment to be used for each activity should be then finalized.

4.2. Overall list of equipment's

After the definition of equipment's types, a list of specific equipment's has been discussed during the plenary meeting of BIBA from 7th to 11th November. The utility of these equipment is discussed and some kind of these equipment was presented during the visits of BIBA labs such as the Fischer Technik. The list of the proposed equipment is presented in table 3. The equipment number will be used in the next sessions to show the activities – equipment's associations. Each equipment is differentiated also by the type number taken from figure 3. This table presents also for each equipment the HEI partners which are interested to use it.

Table 3 Global list of equipment

Equipment number	Equipment	HEI Partner				Type
		IIT	UCAR	IUT	ECC	
1	FischerTechnik Learning Factory	X	X	X	X	3
2	Technivib simulator Expert				X	6
3	ESP32-CAM WiFi Module	X	X			1
4	100 * RFID Adhesive readers, 50x50mm RFID	X	X			1
5	RFID USB ID reader	X	X			1
6	Sensor kit V2.1 42IN1	X	X			1
7	Development kits	X	X			1
8	Camera 5.0MP Jetson Nano	X	X			1
9	KIT EDUCATION LoRa 868MHZ IOT DRAGINO Pour Arduino	X	X			1
10	Kit Raspberry PI4 2G official		x			1
11	Server	X	X			2
12	PC Notebooks	X				2
13	Tablet - Android 10 - 32 Go	X	X	X		2
14	Screen for PC	X	X			2
15	Car robot for Raspberry Pi 4	X	X			4
16	TINKERKIT BRACCIO ROBOT TO-5000	X	X			4
17	Oculus Quest 2		X			7
18	3D printer	X				5

19	3D Scanner Creality CR-SCAN 01 Upgraded Kit	X				1
20	CNC lazer machine LASER GS5030 50W	X				5
21	FILAMENT PLA 1.75MM 1KG BLEU	X				5
22	STM32F407G-DISC1		X			1
23	Development kit SX1278 E32-868T20D 868mhz		X			1
24	Datalogic Magellan 1500i scanner			X		2
25	Webcam HDR 4K Dell UltraSharp			X		2
26	Duckiebot MOOC	X				4
27	Arduino UNO Kit	X				1
28	Automation system simulation			X		6

4.3. Activity-equipment selection for UCAR

The table 4 presents the equipment selected by UCAR and the association with the activities that will use each one of them. The last column at the right of this table presents the number of equipment to use by activity while the last line presents the number of activities for which each equipment will be used. The number of activities for each equipment (last line of the table) is important and significant (between 4 and 15) which justify the utility of equipment selected by UCAR.

Table 4 Activity-equipment selection for UCAR

Activities	Equipments																		Number of equipments per activity
	1	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	22	23	
Act 1.1		x			X											x			3
Act 1.2	x													x	x				3
Act 1.3																			0
Act 1.4																			0
Act 1.5																			0
Act 2.1																			0
Act 2.2	x													x	x				3
Act 2.3	x													x	x				3
Act 2.4						x			x										2
Act 2.5																			0
Act U.1.1	x					x	x	x	x	x	x	x	x	x	x		x	x	13
Act U.1.2	x		X	X	X	x		x	x	x	x	x	x	x	x		x	x	15
Act U.1.3							x												1
Act U.1.4																x			1
Act 3.1	x		X	X				x		x	x	x	x	x	X		x	x	12
Act 3.2	x		x	x										x	X				5
Act 3.3																			0
Act 3.4	x		x	x	X	x			x					x	X				8
Act 3.5	x				X	x			x					x	X				6
Act 4.1	x													x	X				3

Act 4.2	x				X	x			x					x	X				6
Act 4.3																x			1
Act 4.4																x			1
Act U.2.1			x	x	X	x		x	x	x	x	x	x			x	x	x	13
Act U.2.2																			0
Act U.2.3	x													x	X				3
Act U.2.4					X	x			x										3
Act U.2.5								x		x	x	x	x				x	x	7
Act 5.1																			0
Act 5.2	x													x	X				3
Act 5.3																			0
Act 5.4																			0
Act 5.5																			0
Act 6.1																			0
Act 6.2																			0
Act 6.3																			0
Act 6.4		X					x												2
Act 6.5					X	x			x										3
Act U.3.1																			0
Act U.3.2	x	X			X	x	x		x					x	X				8
Act U.3.3																			0
Act U.3.4																			0
Act U.3.5	x	X			X	x	x		x					x	X				8
Number of activities per equipment	15	4	5	5	10	11	5	5	11	5	5	5	5	15	15	5	5	5	

4.4. Activity-equipment selection for IIT

The table 5 presents the equipment selected by IIT and the association with the activities. The last column at the right of this table presents the number of equipment to use by activity while the last line presents the number of activities for which each equipment will be used. The number '0' in the last column means that the activity will not be used by the partner, or it doesn't require equipment to be developed.

Table 5 Activity-equipment selection for IIT

Activities	Equipment																						Number of equipment per activity
	1	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	26	27	28	
Act 1.1		x	x				x							x	x	x					x			7
Act 1.2	x									x										x				3
Act 1.3																								0
Act 1.4																								0

Act 1.5																							0
Act 2.1																							0
Act 2.2	x															X			x				3
Act 2.3	x				x											X			x				4
Act 2.4						x		x		x	x	x	x	x	x	x							9
Act 2.5																							0
Act U.1.1	x	x	x			x		x	X	x	x	x	x	x	x	X			x				14
Act U.1.2	x				x		x	x		x	x	x	x	x	x	x			x				12
Act U.1.3		x	x			X			X														4
Act U.1.4					x					x				x	x	x	x	x	x				8
Act 3.1	x				x	X				x				x	x	x	x	x	x	x			11
Act 3.2	x																		x				2
Act 3.3					x	x											x	x					5
Act 3.4	x				x		x	x			x	x	x						x				9
Act 3.5	x					x		x			x	x	x						x				8
Act 4.1	x				x					x									x				4
Act 4.2	x				x	x	x	x		x	x	x	x						x				10
Act 4.3														x	x	x							4
Act 4.4					x												x	x	x				4
Act U.2.1					x	x	x	x		x	x	x	x				x	x	x				11
Act U.2.2						x				x							x	x	x				5
Act U.2.3	x				x														x				3
Act U.2.4							x	x			x	x	x	x	x								7
Act U.2.5						x								x	x								3
Act 5.1					x																		1
Act 5.2	x				x														x		x	x	5
Act 5.3																					x	x	2
Act 5.4																					x	x	2
Act 5.5																							0
Act 6.1														x	x					x	x	x	5
Act 6.2																							0
Act 6.3																				x	x	x	3
Act 6.4		x	x				x		X					x	x								6
Act 6.5							x	x			x	x	x							x			6
Act U.3.1														x	x								2
Act U.3.2	x	x	x				x	x	X		x	x	x						x	x	x	x	13
Act U.3.3																							0
Act U.3.4																				x	x	x	3
Act U.3.5	x	X	x				x	x	X		x	x	x						x				10
Number of activities per equipment	15	6	6	0	13	10	10	11	5	10	11	11	11	12	12	7	6	6	6	15	6	7	7	

4.5. Activity-equipment selection for ECC

The table 6 presents the equipment selected by ECC and the association with the activities. Although only three equipment have been selected by ECC, this equipment will be widely used by the selected activities. Indeed, the number of activities is between 13 and 23 as noticed in the last line.

Table 6 Activity-equipment selection for ECC

Activities	Equipments		Number of equipments per activity
	1	2	
Act 1.1			0
Act 1.2	x	x	2
Act 1.3	x	x	2
Act 1.4		x	1
Act 1.5			0
Act 2.1		x	1
Act 2.2	x		1
Act 2.3	x	x	2
Act 2.4		x	1
Act 2.5	x	x	2
Act U.1.1	x	x	2
Act U.1.2	x	x	2
Act U.1.3	x	x	2
Act U.1.4	x	x	2
Act 3.1	x		1
Act 3.2	x		1
Act 3.3	x		1
Act 3.4	x		1
Act 3.5			0
Act 4.1	x		1
Act 4.2	x		1
Act 4.3	x		1
Act 4.4	x	x	2
Act U.2.1	x		1
Act U.2.2	x		1
Act U.2.3	x	x	2
Act U.2.4			0
Act U.2.5			0
Act 5.1	x		1
Act 5.2			0
Act 5.3			0

Act 5.4			0
Act 5.5	x		1
Act 6.1			0
Act 6.2			0
Act 6.3			0
Act 6.4			0
Act 6.5			0
Act U.3.1			0
Act U.3.2			0
Act U.3.3	x		1
Act U.3.4			0
Act U.3.5			0
Number of activities per equipment	23	13	

4.6. Activity-equipment selection for UIT

The table 7 presents the equipment selected by UIT and the association with the activities. As for the other partners, some activities will not be selected or doesn't require any equipment to be developed according to UIT. The choice of each equipment is justified by many activities to use it (between 19 and 28).

Table 7 Activity-equipment selection for UIT

Activities	**Equipment**					**Number of equipment per activity**
	1	**13**	**24**	**25**	**28**	
Act 1.1	x			x		2
Act 1.2	X	X	X	X	X	5
Act 1.3	X	X	X	x	X	5
Act 1.4		X	X	x		3
Act 1.5		X	X	X		3
Act 2.1	X	X	X	X	X	5
Act 2.2		x	X	X	X	4
Act 2.3		x	x	X	X	5
Act 2.4	X	X		x	X	4
Act 2.5		X			X	2
Act U.1.1	X	X	X	X	X	5
Act U.1.2	X	X	X	X	X	5
Act U.1.3	X	X		x	X	4
Act U.1.4	X	X	X	X	X	5

Act 3.1		X	X	X		3
Act 3.2	X	X		x	X	4
Act 3.3	X	X	X	X		4
Act 3.4	X	X	x	x	X	15
Act 3.5		X	X	X		3
Act 4.1	X	X				2
Act 4.2	X	X		X		3
Act 4.3		X	X	x	X	4
Act 4.4	X	X		X		3
Act U.2.1	X	X	X	X		4
Act U.2.2						0
Act U.2.3	X	X	X	X	X	5
Act U.2.4						0
Act U.2.5		X		x	X	3
Act 5.1						0
Act 5.2			X	X		2
Act 5.3						0
Act 5.4						0
Act 5.5						0
Act 6.1			X	x	X	3
Act 6.2						0
Act 6.3	x	X			X	3
Act 6.4						0
Act 6.5						0
Act U.3.1	X	X		x	X	4
Act U.3.2		x			x	2
Act U.3.3						0
Act U.3.4						0
Act U.3.5						0
Number of activities per equipment	19	28	19	27	20	