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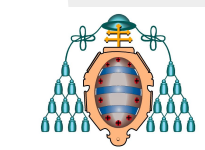
Requirement-Based Training Development and Pedagogical Aspects for Teaching Automation 4.0. Case study: "*Erasmus+ ETAT Project*"

P3 - UNIOVI Team

Felipe Mateos, Reyes Poo, Antonio Robles y José A. Sirgo



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Requirement-Based Training Development and Pedagogical Aspects for Teaching Automation 4.0. Case study: "*Erasmus+ ETAT Project*"

- Introduction: ETAT Project
- Methodology: ETAT Didactic Approach
- Preliminary Data from ETAT Project
- Procedure for Didactic Modules Definition
- Next Steps in ETAT Project
- Conclusions

Project Duration

Project start: 2020
Project duration: 3 years

Funding

ETAT is an Erasmus+ Project. It is supervised by EAECA and supported by the European Union with about 1 million Euros.

Project coordination

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Program Country Universities

Partner Country Universities

University of Antwerp

Carinthia University of Applied Sciences – Fachhochschule Kärnten

U.PORTO

STU Slovak University of Technology in Bratislava

Universidad de Oviedo

unibz – Freie Universität Bozen, Libera Università di Bolzano, Università Lieda de Bulsan

EDUNET WORLD ASSOCIATION

Rajamangala University of Technology Tawan-ok

KMUTNB

EEC

ETAT

http://etat-erasmus.com

Co-funded by the Erasmus+ Program of the European Union

ETAT Education & Training for Automation 4.0 in Thailand

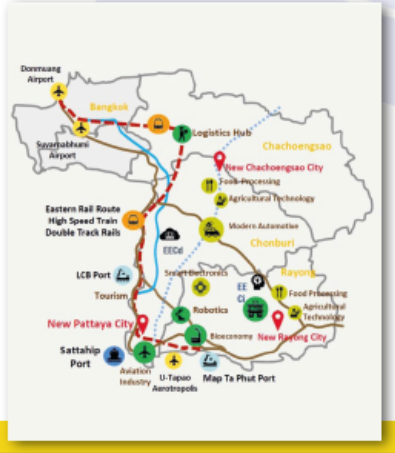
Sustainable qualification for the Thailands Eastern Economic Sector

Since 2018, Thailand has been undergoing a major transformation process. The result of this transformation process will be Thailand 4.0, characterized by a digitized, integrated economic and social system and advanced infrastructure.

A key component of Thailand 4.0 is the Eastern Economic Corridor (EEC), an area of more than 13,000 square kilometers spanning the three provinces of Chonburi, Rayong and Chachoengsao southeast of Bangkok.

The focus of economic development in the EEC is on digital industries, electronics, robotics, aviation and automotive engineering, among others. The technologies used are intended to implement the principles of Industry 4.0. The close linking of information technology with classic automation technologies in the sense of a digital transformation of Industrie 4.0 (Automation 4.0) is of particular importance for the efficient development of the EEC.

An essential basis for the implementation of the EEC project is the availability of highly qualified specialists who can develop, operate and maintain the corresponding production, manufacturing and logistics technologies. In this context, the educational institutions in the EEC, especially the universities, play a central role in the qualification of skilled workers for Thailand 4.0.



Project Focus

The ETAT project focuses on strengthening technical qualifications at Thai universities in the field of Industry 4.0, industrial automation and smart production, with the aim of improving graduate employability and lifelong learning (LLL) by introducing European educational standards using practical examples.

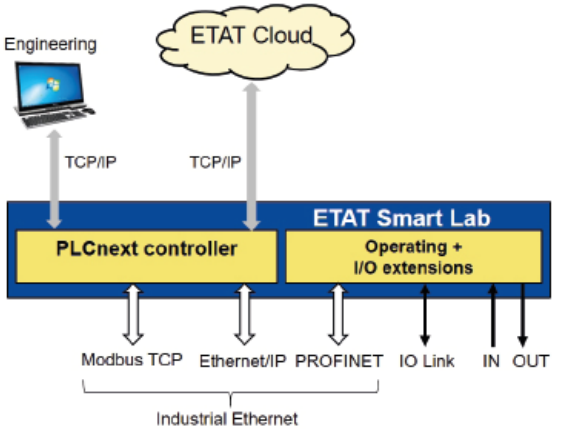
To achieve this, 6 European partner universities are working together with 6 Thai universities and the Eastern Economic Corridor – Human Resource Development Centre (EEC-HDC) in different subprojects.

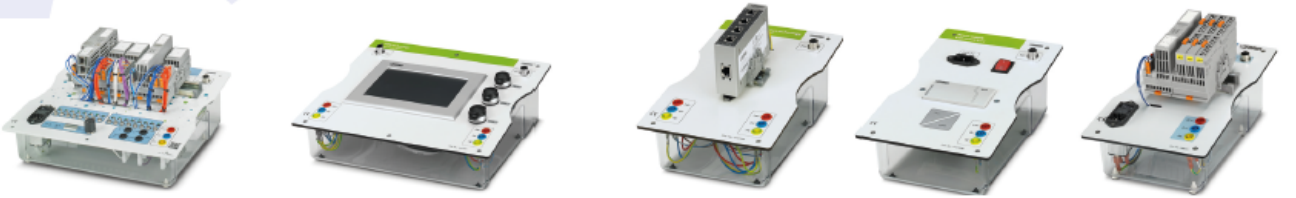
Specific Aims

- Modernization of Higher Education in Thailand based on the experience of European countries;
- Increase the employment rate of university graduates and implement the concept of Life-Long learning with the help of special training modules in the field of industrial automation;
- Development of partnerships with enterprises;
- Improve the quality and relevance of Higher Education in Thailand in the field of industrial automation;

Outcomes

- Establishment of 6 certified ETAT Training Centers at partner universities, which will be equipped with 24 special training places (respectively 4 ETAT Smart Labs per Thai university; technology by Phoenix Contact);
- Establishment of a platform for distance learning and cooperation between the partners for providing E-Learning & Cloud-based learning courses and for exchange of didactical documents and information;
- Practice-oriented qualification in the subject area of Industry 4.0 for 1000 students within 5 years after Establishment of the ETAT Training Centers;





Various learning panels assemble into a multifunctional ETAT Smart Lab core.

Methodology: ETAT didactic approach

Outcome-based Education (OBE)

Learning Outcome (LO) =
Courses + Time + Resource

INPUT

Preliminary Data from ETAT Project

- Automation 4.0
- New & Updated curricula
- Technological process

Needs Analysis

ETAT Smart Labs

PROCESS

Possible Topics

Selection and development

Didactic Modules

OUTPUT

Learning Courses

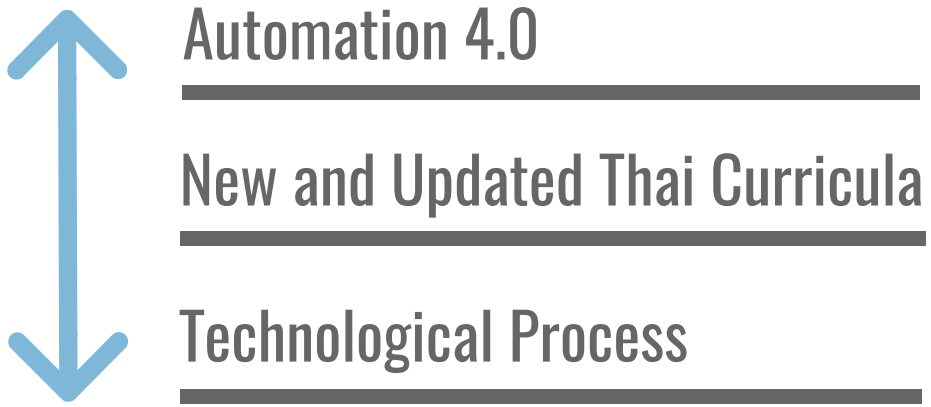
Curricula of Higher Ed. in Thailand

New/Updated

In terms of didactic modules and learning courses development, Thai partners had to take the responsibility themselves. Nevertheless, they have support from European partners and can benefit from their materials and experiences

Preliminary Data from ETAT Project

These first three stages provide the starting information for the development of the procedure that has been followed up to the detailed definition of several didactic modules. They include theoretical, practical and assessment materials necessary for the modernisation of the curricula.



Preliminary Data from ETAT Project

Automation 4.0

First, there was the need to identify relevant areas and new trends in the field of automation (→ Industry 4.0 → Automation 4.0)

Based on the requirements that Thai partners stated in the project applications, the essential Automation 4.0 topics for them were:

- Cyber-physical Systems an IIoT
- Advanced PLC programming
- Feedback Control Technology
- Robotics
- HMI Systems
- Big Data Analysis

These preliminayry requirements will be then combined with Needs Analysis research and they will reveal the total requirements of the relevant stakeholders

Preliminary Data from ETAT Project

New and Updated Thai Curricula

P8

BUU - BURUPHA UNIVERSITY

SCADA System, Embedded system, Control System **60**

P9

RMUTTO - RAJAMANGALA UNIV. OF TECHNOLOGY TAWAN-OK

Hands-on for SCADA systems, Embedded system, Control systems **60**

P10

RRU - RAJABHAT RAJANAGARINDRA UNIVERSITY

Information Tecnhology (IoT), Computer Science (IoT), Microprocessor **48**

P11

KMUTNB - KING MONGKUT´S OF TECHNOLOGY NORTH BANGKOK

Industrial IoT, Industrial robotics, Machine learning with big data, Automated Guiadance systems, Automatic traffic/Logistics solution **100**

Modern automation technology in vehicles, Scalable manufacturing execution system for industry (MES) **26**

P12

KU - KASETSART UNIVERSITY

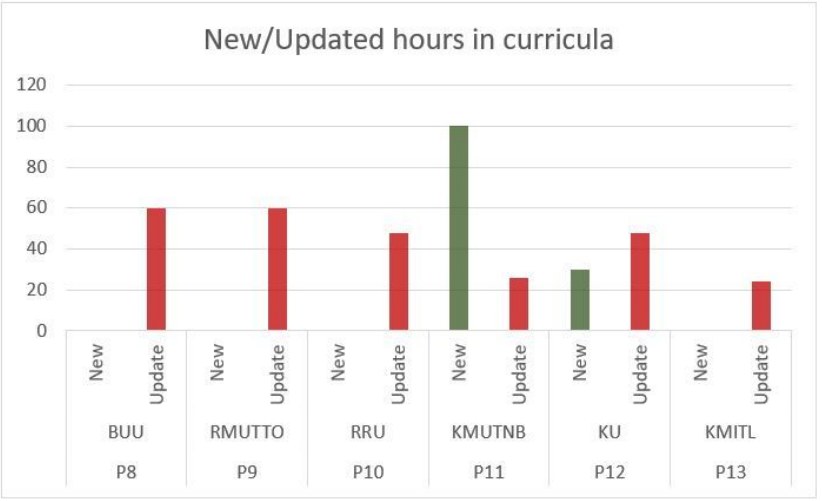
Basics of data science for industrial **30**

Decision support system, Data mining tech. and applications, Manufacturing information system, Expert system, Knowledge management **48**

P13

KMITL - KING MONGKUT´S INSTITUTE OF TECHNOLOGY LADKRABANG

Big data analysis for industrial applications, Web user interface for industrial applications, E-learning and cloud-based learning **24**



Secondly, it has been gathered general information on newly created courses, or courses in need of updating, corresponding to the syllabus of certain degrees an the Thai universities

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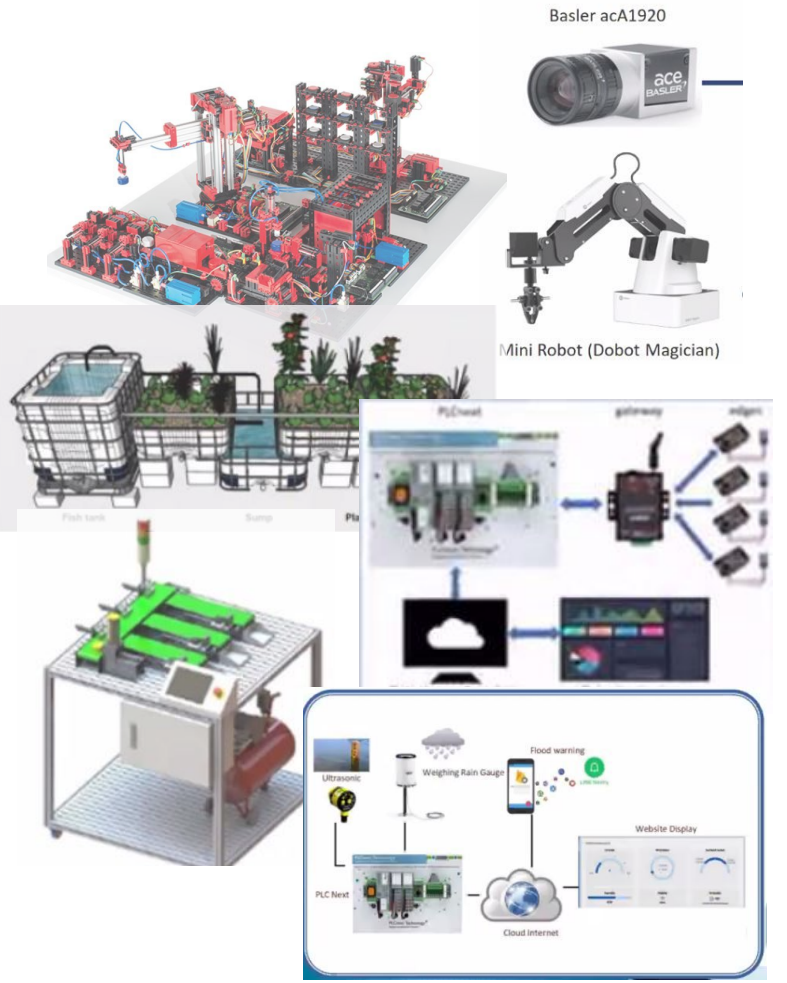
Preliminary Data from ETAT Project

Technological Process

Third, it is a collection of specialization/application fields for each Thai partner, which are required for the definition of a real (process) on which develop practical applications.

Each Thai partner requires different Real/Simulation Process Model according to the expertise and nearby industries:

- Smart Factory (BUU)
- Smart City & Home (KMITL, KU)
- Agriculture / Smart Farming (RRU)
- Robotics (RMUTTO)
- Logistics, Traffic, Energy & Environment (KMUTNB)



Procedure for Didactic Modules Definition

These previous three stages provide the starting information for the development of the procedure that has been followed up to the detailed definition of several didactic modules. They include theoretical, practical and assessment materials necessary for the modernisation of the curricula.

- Needs Analysis
- Concept of ETAT Smart Labs
- Topics and Horus in Curricula
- Didactic Modules Distribution
- Preparation of Didactic Modules

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Procedure for Didactic Modules Definition

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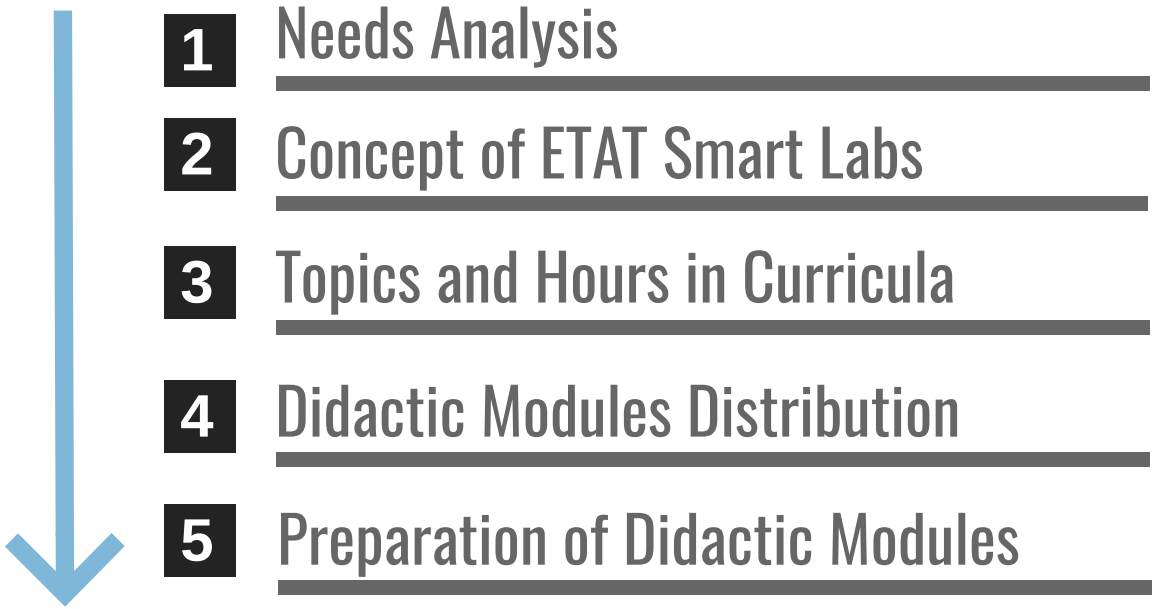
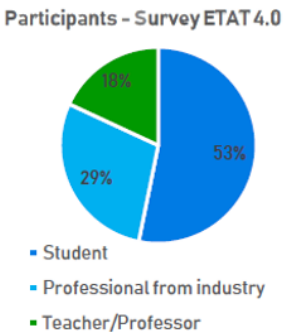


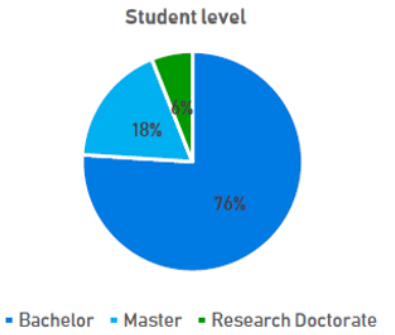
Procedure for Didactic Modules Definition

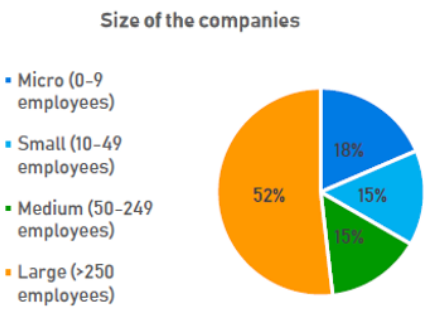
1 Needs Analysis (Sample overview)

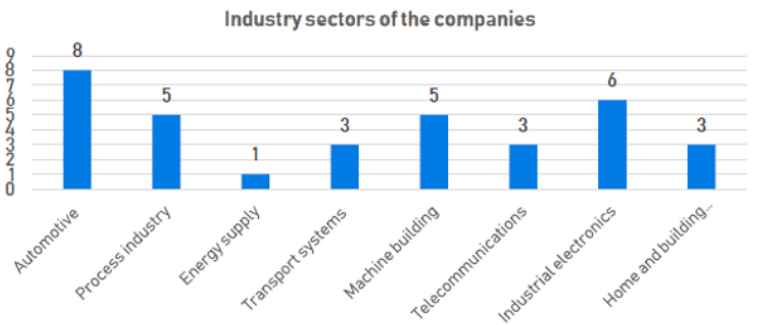
A total of 94 participants took part at this survey:

- 50 of the participants were students from university in the greater Bangkok area,
- 17 of the participants were teachers/professors from Thai universities at Bangkok and
- 27 participants were professionals from Thai industry









Procedure for Didactic Modules Definition

Needs Analysis (Technical features)

PROGRAMMING

IEC 61131-3
HMI/SCADA Systems
Python
C/C++
Matlab/Simulink
Java, Node-Red

INDUSTRIAL COMM.

Ethernet/IP
Modbus TCP
PROFINET
Profibus
IO-Link
AS-I, DeviceNet

IoT PROTOCOLS

MQTT
OPC UA
REST API
HTTP

WIRELESS COMM.

Wi-Fi
Bluetooth
GSM

CLOUD PLATFORMS

Google Cloud
Microsoft Azure
IBM Cloud
Proficould

Procedure for Didactic Modules Definition

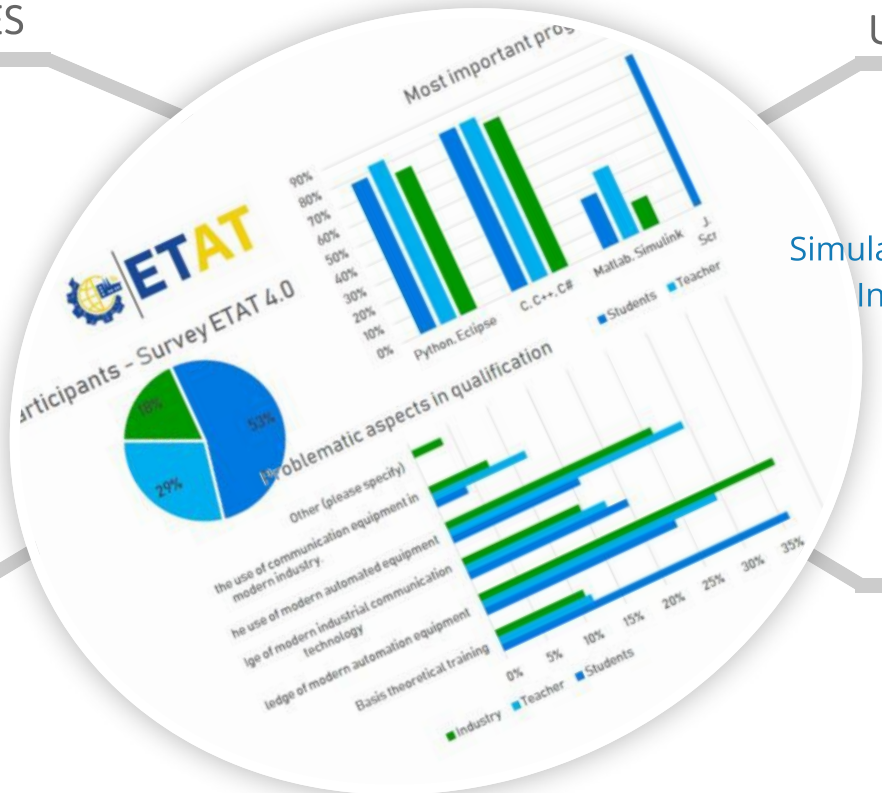
1 Needs Analysis (Teaching possibilities)

TRAINING PREFERENCES

Face-to-Face
E-Learning
Remote Lab
Practical classes in lab.
Hands-on workshops
Real-life case studies
<=15 students
<=10 employees, 4 days

PREF. APPLICATIONS

Robotic station
Home Automation
Smart farming
Assembly system



USES OF EQUIPMENT

Analysis and design
Control programming
HMI development
Simulation and process control
Industrial communications

MANUFACTURERS

Phoenix Contact
Mitsubishi
Siemens
Rockwell Automation

Procedure for Didactic Modules Definition

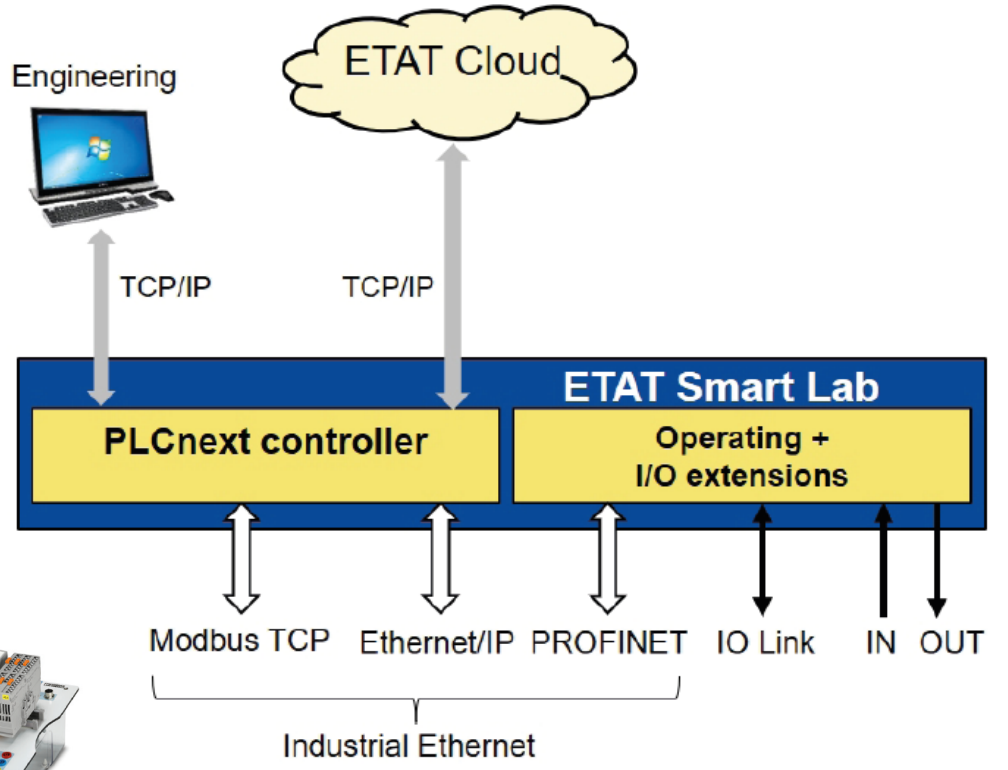
1 Needs Analysis (Some problems)

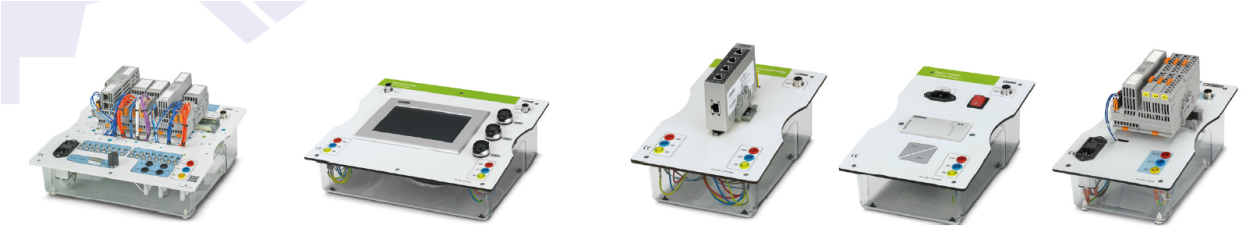
- Specialists at the Thai enterprises and students of technical topics have the **lack of knowledge in Automation 4.0** and at the universities, it lacks of modern equipment.
- Demand of opening of the **hands-on training centres** in the profiling universities of the EEC.
- **Lack of didactical materials and knowledge** of the Thai university staff members in Industry 4.0 automation technologies widely used in EU countries.
- **Modernization and reform of higher education** in technical subject.
- Curricula in Thai HEI in industrial automation have lack of hands-on trainings and do not include the application of practice-oriented and work-oriented **ICT technology in Automation Engineering**.
- Lack of capacities to **translate the teaching materials**, provided by the EU partner universities to the national languages.

2 Concept of ETAT Smart Labs

The goal was to build a modular and flexible system where the educational requirements of Industry 4.0 could be implemented. This system was named ETAT Smart Lab (ESL). It was designed having in mind the most voted technologies in Needs Analysis.

One of the objectives of ETAT project is to stablish one ETAT training centre at each partner Thai university. Each training centre will be composed of 4 ESL and a specific technological process.





Various learning panels assemble into a multifunctional ETAT Smart Lab core.

3 Topics and Hours in Curricula

Teaching needs are different in Thai university partners... Some courses are more oriented to Computer Science, others to Data Management and other ones to Automation. It was a challenge to satisfy these related but, at the same time, diverse requirements.

The approach was to **identify a manageable number of didactic modules**, which could be used in all their extent or in parts to teach all the different courses included in the project. The process to do that was the following:

1. Design a spreadsheet to gather and represent information, about topics from Needs Analysis and corresponding teaching hours (theory and lab), for each course.

2. Tables were filled out by each Thai partner. They distributed the hour loud among topics relevant for each course.

3. Analysis of the results allowed a detailed identification of number theoretical and practical teaching hours in the relevant topics for each course.

Procedure for Didactic Modules Definition

3 Topics and Hours in Curricula (Original information from ETAT project - Example P11)

Partner Nº	**P11**
Name	**King Mongkut's University of Technology North Bangkok**
Acronym	**KMUTNB**
Staff member	*Saman Kumpakeaw*
Real/simulation process model	**LOGISTICS & TRAFFIC / ENVIRONMENT & ENERGY**
Hours to update	**26**
New course hours	**100**

Course	Industrial IoT	Industrial Robotics	Machine Learning with Big Data	Automatic Guidance Systems in Industry	Automatic Traffic/ Logistic Solution	Modern Automation Technology in Vehicles	Scalable Manufacturing Execution System (MES) for Industry
Center							
Update/New	NEW	NEW	NEW	NEW	NEW	UPDATE	UPDATE
Level	Beginner	Intermediate	Intermediate or advanced	termediate or advance	Intermediate or advanced	Beginner of intermediate	Intermediate
ECTS	2	2	2	2	2	2	2
% Update	100%	100%	100%	100%	100%	70%	60%
Hours to update	20	20	20	20	20	14	12
THEORY (h)							
PRACTICE (h)							
Students	100	50	50	50	50	50	50
Teachers	10	10	10	10	10	10	10
Equipments	ETAT Smart Labs PLC with IoT features Sensors and actuators Multimeter/Oscilloscopes Computer	ETAT Smart Labs PLC with IoT features Sensors and actuators Robot manipulators Simulation programs Multimeter/Oscilloscopes Computer	Computers Sensors and actuators for PBL-projects	ETAT Smart Labs Computers Simulation software Automated Guided Ve Sensors and actuator for PBL-projects	ETAT Smart Labs Computers Simulation software Sensors and actuator for PBL-projects	Computers Simulation software Sensors and actuator for automatic systems of EV	ETAT Smart Labs Computers Simulation software

Procedure for Didactic Modules Definition

3 Topics and Hours in Curricula (Collecting information of topics - Example P8)

From ETAT project	Please, fill in the yellow cells, if applicable								
Partner Nº	P8						Hours to update		
Name	Burapha University						120		
Acronym	BUU								
Staff member	*Prajaks Jitngernmadan*								
Real/simulation process model	SMART FACTORY								
Course	Hands-on Automation Technology for SCADA System	24	24	Industrial Embedded Systems for Machine Control and Monitoring	18	18	Industrial Automation	18	18
		Hours			Hours			Hours	
WP3. D3.4: TEACHING MATERIALS (lessons, practices)		THEO	PRAC		THEO	PRAC		THEO	PRAC
from Needs Analysis									
Specific content	Introduction to automation technology; programmable logic control usage, plc programming, input data, output data;			Introduction to industrial embedded systems, embedded microcontrollers; embedded programming; real-time operating			Industrial sequence control; components and structure of the industrial automation; programmable logic controllers (PLC); basic		
Programming									
IEC 61131-3	IEC 61131-3 basics and examples	2	2	IEC 61131-3 basics and examples	2	2	IEC 61131-3 basics	1	2
HMI/SCADA systems	HMI/SCADA systems (practical)	6	6				HMI/SCADA system	3	3
Python	Programming Python	6	6	Programming Python	2	2	Programming Python	1	2
C/C++/C#				Programming C/C++/C#	2	2			
Robots/ROS programming									
Matlab/Simulink									
Java/JavaScript									
Node-Red	Programming Node-Red	2	2	Programming Node-Red	2	2			
SQL Database									
Industrial communications									
Centralized IO									
Ethernet/IP	Ethernet/IP configuration	2	2	Ethernet/IP configuration	1	1	Ethernet/IP configuration	1	2
Modbus TCP/RTU							Modbus TCP configuration	1	2
PROFINET	Profinet standard and configuration		2				Profinet configuration	1	2
IO-Link									
OPC standard							OPC configuration	2	1
Profibus									
AS-Interface									
DeviceNet									

Procedure for Didactic Modules Definition

4 Didactic Modules Distribution (First teaching materials list)

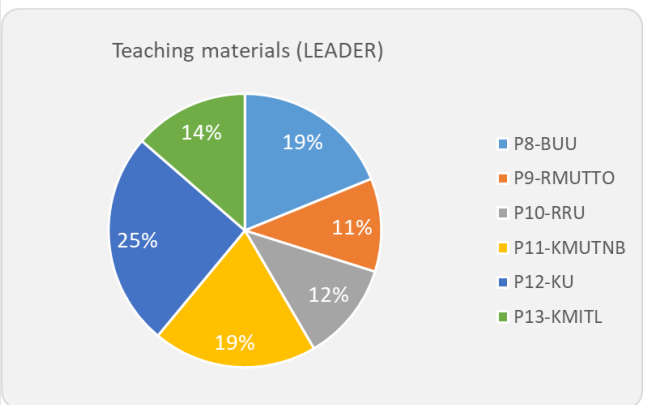
WP3. D3.4 & D3.5: *Teaching materials*

	THEO (D3.4)	PRAC (D3.5)	Teaching materials	Hours THEO (D3.4)	Hours PRAC (D3.5)	Thai partners LEADER	Contributor	Interested
Programming	**34**	**44**	IEC 61131-3 + **Centralize IO**	4	8	P11-KMUTNB	P10-RRU	P8-BUU
			HMI/SCADA, **OPC, OPC UA, MES**	12	9	P8-BUU	P11-KMUTNB	P9-RMUTTO
			Python	6	8	P10-RRU	P8, P11, P12	P9, P13
			C/C++/C#	2	2	P8-BUU	P9-RMUTTO	P10, P11, P13
			Robot/ROS programming	4	8	P11-KMUTNB		
			Matlab/Simulink		2	P9-RMUTTO		
			Java/JavaScript + **Node-Red**	3	5	P8-BUU	P11-KMUTNB	P9, P12, P13
			SQL Database	3	2	P12-KU		
Integration	**14**	**19**	**Ethernet/IP**	2	2	P8-BUU	P9-RMUTTO	P10 to P13
			Modbus TCP	2	3	P8-BUU	P11-KMUTNB	P9-RMUTTO
			PROFINET	1	2	P8-BUU	P13-KMITL	P9, P10
			IO-Link		1	P9-RMUTTO		
			IoT comm. (MQTT, REST API)	5	5	P8-BUU	P10-RRU	P9, P13
			Wi-Fi	1	2	P11-KMUTNB	P10-RRU	P8, P9
			Google Cloud	2	3	P13-KMITL	P12-KU	P11-KMUTNB
			Proficloud	1	1	P8-BUU	P10-RRU	P9, P13
Topics in Industry 4.0	**21**	**17**	Industry 4.0/Ciber Systems & IoT	3	2	P10-RRU	P8-BUU	P9, P11, P13
			Advanced PLC Prog. **PLCnext**	3	3	P8-BUU	P12-KU	P9, P11
			Feedback Control Technology	1	1	P9-RMUTTO		
			Robotics	5	2	P9, P11		
			Big Data Analysis	9	9	P12-KU		P11, P13
Real/Sim. Process Model	**12**	**27**	Smart Factory (BUU)	5	4	P8, P12		
			City & Home (KU, KMITL)		5	P13-KMITL		
			Agriculture - Smart Factory (RRU)	4	4	P10-RRU		
			Robotics (RMUTTO)	1	2	P9-RMUTTO		
			Logistics & Traffic (KMUTNB)	2	9	P11-KMUTNB		
			Environment & Energy (KMUTNB)		3	P11-KMUTNB		
Other topics	**13**	**11**	Data analysis	6	4	P12-KU		
			Process simulation	1	3	P13-KMITL		
			SAE Automation Level	1		P11-KMUTNB		
			Vision systems		1	P9-RMUTTO		
			Augmented/Virtual reality	1		P8-BUU		
			Digital twin	1		P8-BUU		
			Pattern recognition	3	3	P12-KU		
	94	**118**		94	118			
	44%	56%						
Total of hours	212							

Procedure for Didactic Modules Definition

4 Final Didactic Modules Distribution

		Hours					Final distribution		
ID	Didactic modules (Teaching materials)	THEO (D3.4)	PRAC (D3.5)	THEO hours	PRAC hours	Total of Hours	LEADER	Contributor	Interested
M1	HMI/SCADA systems	12	9	75	79	154	P8-BUU	P11-KMUTNB	P9-RMUTTO
M2	IEC 61131 programming	5	9				P11-KMUTNB	P10-RRU	P8-BUU
M3	Industrial communications	6	10				P11-KMUTNB	P8 BUU	P9 to P13
M4	IoT and cloud technology	11	10				P13-KMITL	P8 to P13	
M5	Node-Red programming	3	5				P8-BUU	P11-KMUTNB	P9, P12, P13
M6	Phyton programming	8	10				P10-RRU	P8, P11, P12	P9, P13
M7	Robotics/ROS programming	9	8				P9-RMUTTO	P11-KMUTNB	
M8	Big data analysis and pattern recognition	21	18				P12-KU		P11, P13
M9	PLCnext technology	3	3	3	3	6	PxC		
M10	ETAT Smart Lab equipment	2	2	2	2	4	WP4		
M11	Real/Sim. Process Model	4	4	4	4	8	P8 to P13		
				84	88	172			
				THEO hours	PRAC hours	Total of Hours			



5 Preparation of ETAT Didactic Modules

- ### Core components

  Core components of didactic modules include Responsible Person, Teaching Hours, Teaching Methods, Teaching Materials and Assessment/Evaluation

  Leader, contributors and interested universities are preparing teaching materials for the development of theoretical and practical classes, in different formats (documents, presentations, videos), teaching mode (face-to-face, e-learning, re-mote labs) and assessment mechanisms.

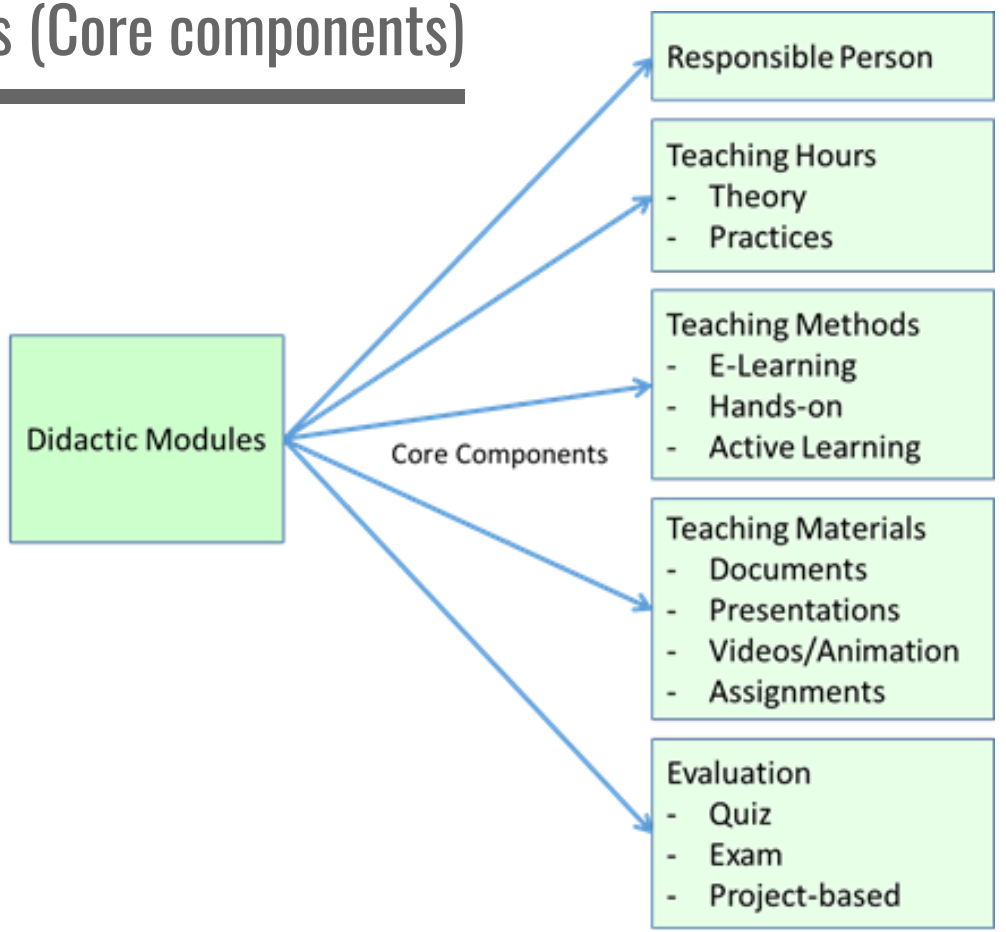
- ### Control list

  A control list has been developed to supervise the progress of this activity. Figure shows, as an example, the supervision of module M2, where it can be seen the state of each material detailed to the level of lessons.

Procedure for Didactic Modules Definition

5 Preparation of ETAT Didactic Modules (Core components)

Leader, contributors and interested universities are preparing teaching materials for the development of theoretical and practical classes, in different formats (documents, presentations, videos), teaching mode (face-to-face, e-learning, re-mote labs) and assessment mechanisms.



Procedure for Didactic Modules Definition

5 Preparation of ETAT Didactic Modules (Control list - Example P11)

ETAT Project

WP3 - PREPARATION **Status overview**

Module number: **M2**
Name of the module: **IEC 61131-3 programming**
Thai LEADER: **P11-KMUTNB (P10-RRU, P8-BUU)**
Contact person: Saman Kumpakeaw **Email:** saman.k@eat.kmutnb.ac.th
Total numbert of hours: 14
Theory: 5
Practice: 9

Focus Course?
Yes

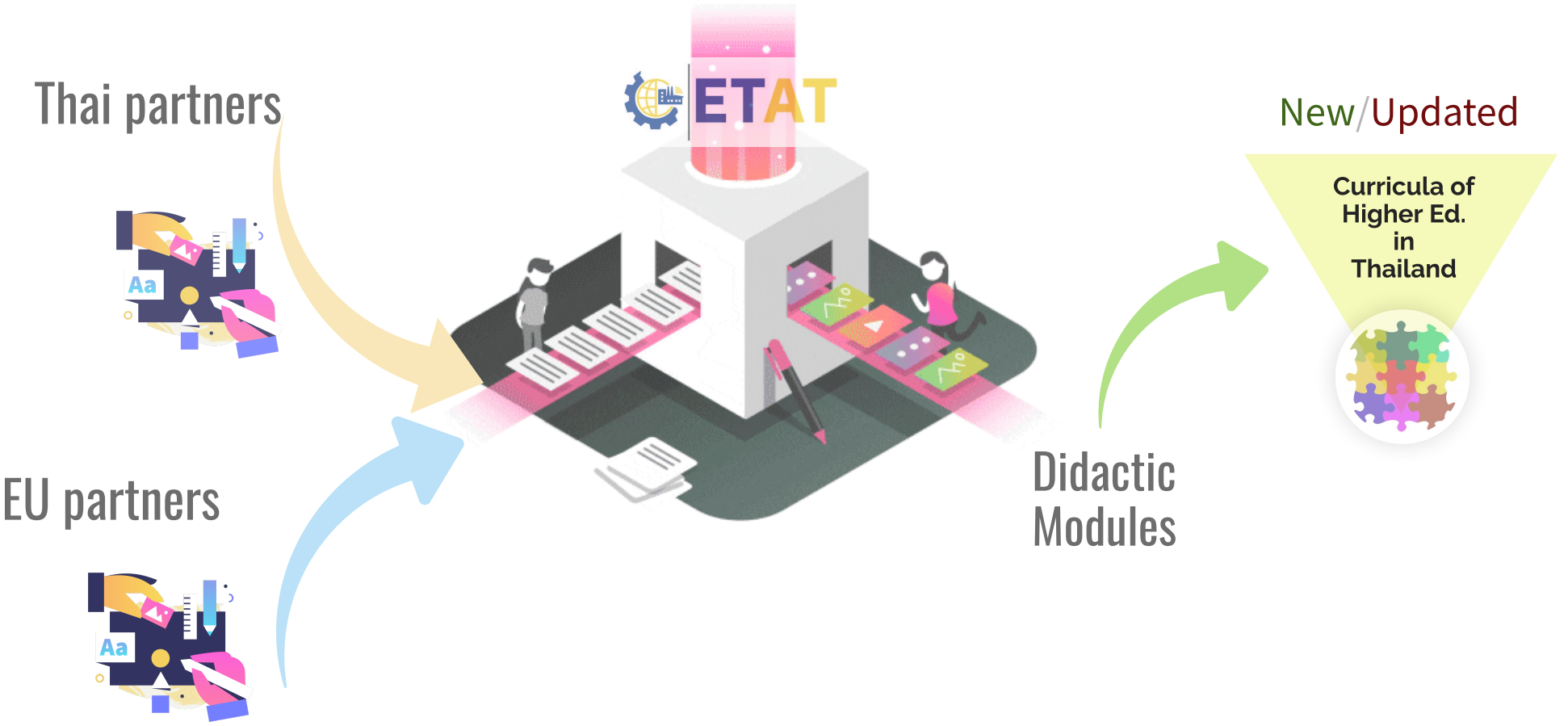
Due Date: 15 May 2022
Progress untill now = 40% (for lecture)

			Pdf/Docx/Documents		Presentation/pptx		Video		Questions	
							E-Learning			
			Thai	English	Thai	English	Thai	English	Thai	English
	THEORY	**Hours**								
Lecture:	Overview of PLCs and the IEC 61131	0,5	In Progress	Revised	Not Started	Completed	Not Started		Not Started	Completed
	IEC 61131-3: data typesand prog. structure	1	In Progress	Revised	Not Started	Completed	Not Started		Not Started	Completed
	Ladder diagram (LD)	1	In Progress	Completed	Not Started	In Progress	Not Started		Not Started	In Progress
	Function block diagram (FBD)	1	Not Started	In Progress	Not Started	In Progress	Not Started		Not Started	In Progress
	Structured text (ST)	1	Not Started	Completed	Not Started	Completed	Not Started		Not Started	In Progress
	Sequential function chart (SFC)	0,5	Not Started	Revised	Not Started	Completed	Not Started		Not Started	Completed
	TOTAL	**5**								

			Lab Assignment		Project		Hands-on Workshop		Done Work	
			Face-to-Face		Face-to-Face		Face-to-Face		Face-to-Face	
			Thai	English	Thai	English	Thai	English	Thai	English
	PRACTICE	**Hours**								
Practice:	PLC hardware configuration	1	Completed				Completed		Not Started	Not Started
	IEC 61131-3 programming in LD with ETAT Smar	2	In Progress				In Progress		Not Started	Not Started
	IEC 61131-3 programming in FBD with ETAT Sma	2	Not Started				Not Started		Not Started	Not Started
	IEC 61131-3 programming in ST with ETAT Smar	2	In Progress				In Progress		Not Started	Not Started
	PLC hardware configuration (basic network con	1	Completed				Completed		Not Started	Not Started
	IEC 61131-3 programming in SFC with ETAT Sma	1	Not Started				Not Started		Not Started	Not Started
	TOTAL	**9**								

Procedure for Didactic Modules Definition

5 Preparation of ETAT Didactic Modules (EU support, ERASMUS+)



Next Steps in ETAT Project

Matching Didactic Modules and Curricula

Deployment and Implementation of Training Activities

Validation, Quality Control and Improvement

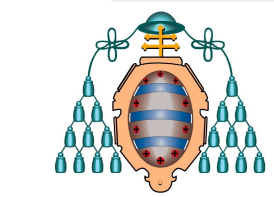
Training Acreditation

Conclusions and Outlook

1. In this work we present how international collaboration is an effective tool for updating curricula and developing teaching materials for Automation 4.0.
2. The approach we propose conforms to OBE (Outcomes-based Education) principles.
3. It is a process that covers from data collection (needs analysis, new curricula, ESL...) to didactic module preparation.
4. In the middle necessary topics are identified and grouped into didactic modules, which can then be used in learning courses.
5. With our ETAT didactic modules, Thai partners can update or create their courses easily. The didactic modules are self-contained including learning materials, teaching methods, and assessment methods.
6. The next step of this work is to implement the created learning materials and collect the feedback.
7. With a suitable quality control and improvement method, the learning materials will suit the learners most. For the outcome of the didactic modules and also the course, the accreditation of the Automation 4.0 training will be needed.

THANK YOU!

Felipe Mateos - P3-UNIOVI Team



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