ETAT Pedagogical Modules for Automation 4.0 Training Program Structure in Training Centres in Thailand

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Abstract. This paper describes the procedure carried out and the results obtained in the preparation of the didactic modules that have been developed for the ETAT Erasmus+ project. These specialised training materials are complemented and supported by the equipment implemented in the training centres set up at 6 Thai universities participating in the project.

The ETAT project background and its objectives, the starting point for the optimised development of the training modules, the criteria for their development and implementation aspects will be described.

The current topics of Industry 4.0 paradigm and a comprehensive needs analysis from students, teachers, and companies in the region have been taken into account. A set of new subjects or their updating in the curricula as well as the type of processes and applications of interest for the different degrees subject to modernisation have also been preferentially considered.

The results, which will take the form of a set of theoretical and practical teaching materials, will include different types of formats (documents, presentations, videos) for face-to-face or e-learning training, examples and application projects, as well as appropriate evaluation mechanisms. The whole process is under strict quality control protocols to ensure the effectiveness and sustainability of the project.

Keywords: ETAT · Pedagogical modules · Training · Automation

1 Introduction

The National Education Act of B.E. 2542–1999 [1] and the Ministry of Education Regulatory Act B.E. 2546–2003 of Thailand has gone through important changes since they was first launched. The guiding principles in education provision are based on lifelong learning for all, participation of all segments of society in education provision, and continuous development of the body of knowledge and learning processes. Moreover,

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Thailand has cooperated with international partners in terms of knowledge and experience sharing. In this context, the Association of Southeast Asian Nations (ASEAN) have been observing the development of the Bologna Process and viewing the Bologna Process, European Higher Education Area (EHEA) and European Research Area (ERA) as a useful model for their regional higher education reforms. In 2018, the Thailand Country Program was signed with key strategic pillars for Thailand's future. The Thai government and business leaders have set in motion an industrial transformation plan known as Thailand 4.0, the next stage of long-term growth. Thailand 4.0 will be characterized by a digitized integrated business and social system and an advanced infrastructure. The plan emphasizes technological innovation and education, assisting digital entrepreneurs, boosting internet access and retraining workers.

A key component of Thailand 4.0 is the Eastern Economic Corridor (EEC) [2], an area of more than 13,000 square kilometres including the three provinces of Chachoengsao, Chon Buri, and Rayong located in the south-eastern part of Bangkok. The technologies used are intended to implement the principles of Industry 4.0 in order to develop a flagship Special Economic Zone in Thailand. The close connection of information technology with classic automation technologies in the sense of a digital transformation of Industry 4.0 (Automation 4.0) is therefore of particular importance for the efficient development of the EEC [3].

For the education purpose, the Education and Training for Automation 4.0 in Thailand (ETAT) project is established. It enables the training and education of future Thai trainers for automation engineers, maintenance engineers, process workers, and students in related fields using non-classic teaching methods such as learning by doing, remote and mobile teaching with innovative technologies as well as Life Long Learning (LLL) and the experience of the European universities.

For developing sophisticated Automation 4.0 courses, an elaborate approach has to be planned and implemented. For this ambitious purpose, we developed a method that helped us creating learning materials step by step. We describe such an approach in the following sections.

2 Methodology

To reach the success of training in engineering education, several approaches and concepts have been designed and implemented. Different engineering majors may have different strong points that have to be assisted. However, some common ideas do exist, e.g. the idea of hands-on training (learning by doing), needs analysis, active learning, etc. [4]. These ideas however underlie the learning theory, including Behaviorism, Cognitivism, and Constructivism [5]. Some works concentrate on learning methods [6] and how to do the assessment of the learned courses [7].

Our approach covers the entire process of Automation 4.0 training. The main concept is also based on the Outcome-based Education (OBE) [8]. The curricula are also designed based on Backward Curriculum Design concept [9]. Our ETAT pedagogical framework consists of 3 main components that have to work together; the Courses, the Time, and the Resource. The combination of these 3 components gives the Learning Outcome (LO)

that we expected at the end of a training. The equation of this relation would be:

$$Learning\ Outcome(\boldsymbol{LO}) = \boldsymbol{C}ourses + \boldsymbol{T}ime + \boldsymbol{R}esource \quad (1)$$

where
LO = Learning outcomes of a course/training
Course = Set of (Knowledge, Skill, Teaching/Learning/Assessment Method)
Time = Set of (Full time, Short course)
Resource = (ETAT Smart Lab (ESL), partner-specific components)

The set of (Knowledge, Skill, Teaching/Learning/Assessment Method) can be derived from the needs analysis of the National Resonance Group (NRG). The address the need analysis we started with the collection of preliminary data that can essentially be obtained from the ETAT project application document:

i. Identification of relevant areas and new trends in the field of automation, especially related to the new paradigm of Industry 4.0.
ii. General information on newly created courses, or courses in need of updating, corresponding to the syllabus of certain degrees at each Thai university.
iii. Fields of specialisation/application in each Thai partner, which are required for the definition of a real system (process) on which to develop practical applications.

Figure 1 shows the overview of the ETAT didactic approach based on the Outcome-based Education (OBE) [8] that recommends to design and develop the learning course by embracing the outcomes of the curriculum first. Hence, the Needs Analysis was done in the first place [10]. Other requirements came from the ETAT Training Centres for hands-on assignments and practices [11]. In the Process-state, topics that better suited the requirements were found. However, not all of these possible topics could be developed. In the following step, the most relevant ones were selected and grouped to create didactic modules. These are self-contained modules for specific knowledge that can be adapted and/or integrated into a learning course easily.

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.

3 Preliminary Data from ETAT Project

3.1 Automation 4.0

First, there was the need to identify relevant areas and new trends in the field of automation, especially related to the new paradigm of Industry 4.0.

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

- Cyber-physical Systems and IIoT
- Advanced OLC Programming
- Feedback Control Technology

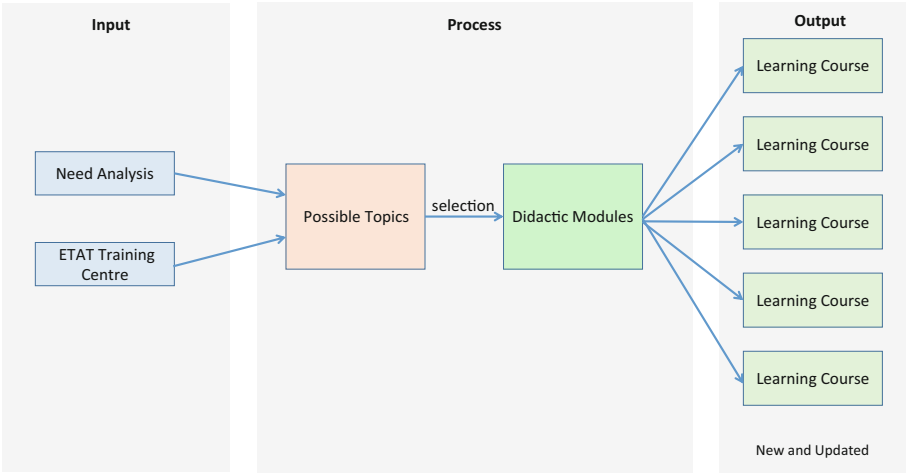

Fig. 1. Overview of the ETAT didactic approach.

- Robotics
- HMI Systems
- Big Data Analysis.

These preliminary requirements will be then combined with Need Analysis research in Sect. 4 and they will reveal the total requirements of the relevant stakeholders.

3.2 New and Updated Curricula

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

As can be seen in the Fig. 2, most of the Thai universities are going to update their curricula. The total number of to-be-updated courses is 266 h (in red in the figure) and the total number of the new courses is 130 h (in green).

3.3 Technological Process

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

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

- Smart Factory (Burapha University)
- Smart City & Home (King Mongkut's Institute of Technology Ladkrabang and Kasetsart University)
- Smart Farming (Rajabhat Rajanagarindra University)

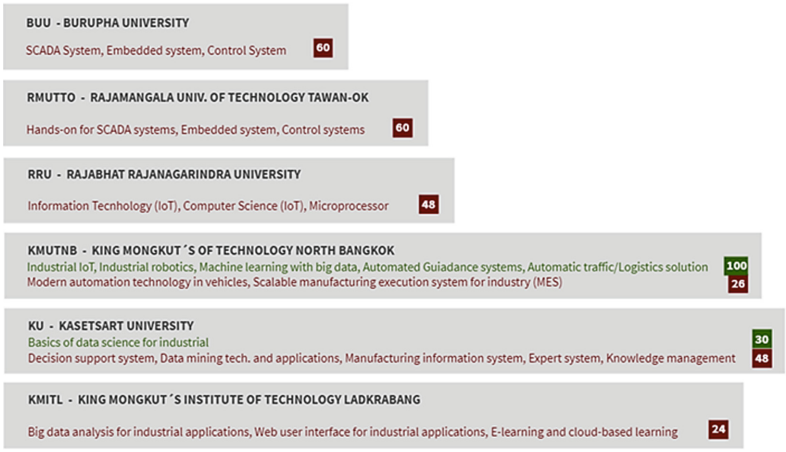

Fig. 2. New and updated at each Thai university.

- Robotics (Rajamangala University of Technology Tawan)
- Logistics, Traffic, Energy and Environment (King Mongkut's University of Technology North Bangkok)

4 Procedure for Didactic Modules Definition

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.

4.1 Needs Analysis

A survey was done in Thailand to lead the selection of technologies that should be implemented in the Smart Labs. It was also used to consult preferences in training and application and to identify some demands and lacks.

Three target groups were considered: university students, university teachers, and industry professionals located in the university environment.

Total number of participants was 94 distributed in 50 students, 17 teachers/professors, and 27 professionals.

According to the technical features, the most voted technologies in each category were:

- Programming (Python)
- Industrial Communication (Ethernet/IP)
- IoT Protocols (MQTT)
- Wireless Communication (Wi-Fi)
- Cloud Platforms (Google Cloud).

In terms of training and application, the results were:

- Training Preferences (Face-to-Face)
- Uses of Equipment (Control Programming)
- Preferred Application (Home Automation)
- Manufacturer (Phoenix Contact).

The survey has also served to highlight 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.

Methodology and complete results of this Needs Analysis can be consulted in [10].

4.2 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.

Figure 3 shows the designed system architecture, common to all Thai partners. A real/simulation process model specific for each partner (see Sect. 3.3) can be attached to the ESL setting up a customized Smart Factory Lab.

A deeper justification of the design can be found in [11], as well as a profuse description of each real station.

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.

4.3 Topics and Hours in Curricula

Teaching needs are different in Thai university partners, as it can be easily seen in Fig. 2. 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:

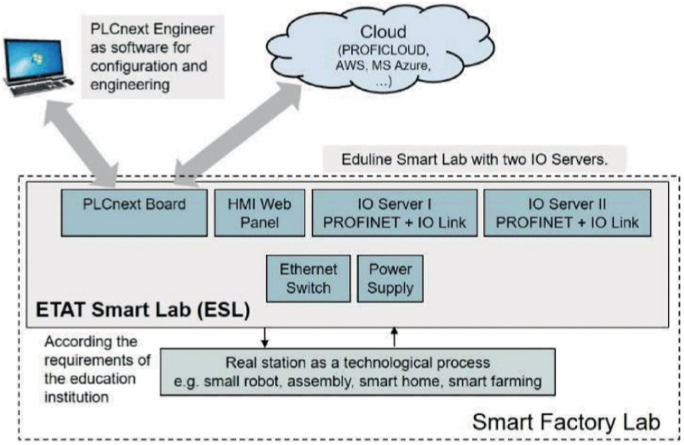

Fig. 3. ETAT smart lab and smart factory lab.

1. Design a spreadsheet to gather and represent information, about topics from Needs Analysis and corresponding teaching hours (theory and lab), for each course. The table was flexible enough to let Thai partners suggest new topics in case that they might be missing in the Needs Analysis research process.
2. Tables were filled out by each Thai partner. They distributed the hour loud among topics relevant for each course. Figure 4 shows a detail involving 3 courses of a Thai University.
3. Analysis of the results allowed a detailed identification of number theoretical and practical teaching hours in the relevant topics for each course.

4.4 Didactic Modules Distribution

Data from the first spreadsheet analysis was used for topic grouping, hour load and definition of general didactic modules for the distribution of work among the ETAT project partners (Leaders/Contributors/Interested).

With this elaborate approach, topics were grouped and reorganised, which led to didactic modules containing several related topics. According to the analysed data, 11 modules were identified:

M1 HMI/SCADA systems
M2 IEC 61131 programming
M3 Industrial communications
M4 IoT and cloud technology
M5 Node-Red programming
M6 Python programming
M7 Robotics/ROS programming
M8 Big data analysis and pattern recognition
M9 PLCnext technology
M10 ETAT Smart Lab equipment

Partner Nº	**P8**	Hours to update
Name	**Burapha University**	**60**
Acronym	**BUU**	
Staff member	*Prajaks Jitngernmadan*	
Real/simulation process model	**CITY & HOME**	

Course	**SCADA System**	**Embedded Systems**	**Control Systems**
Center	Informatics	Informatics	Engineering
Update/New	UPDATE	UPDATE	UPDATE
Level	Bachelor	Bachelor	Bachelor
ECTS	3	3	3
% Update	80%	60%	60%
Hours to update	**24**	**18**	**18**
THEORY (h)			
PRACTICE (h)			
Students	30	25	30
Teachers	2	2	2
Equipments	ETAT Smart Labs	ETAT Smart Labs	ETAT Smart Labs
	PLC (Profinet)	PLC	PLC
	Computers	Computers	Computers
	Simulation Plant	Simulation Plant	Simulation Plant
	Managed Switches	Managed Switches	Managed Switches
	Projector	Projector	Projector

Fig. 4. Topics and hours in curricula.

M11 Real/Sim. Process Model

Number of modules was considered manageable and at the same time enough to cover teaching necessities of every Thai course under concern.

Analysis also allowed to find how many hours a Thai partner would employ in a particular module, summing the needs in all its courses. This information was used to determine who was going to be the responsible Thai University of that topic. Each didactic module has a leader, one or more contributors and one or more interested universities (those for which the module is not so relevant). The leader is the main responsible person, whereas the contributors support him/her and interested ones supervise the final results. Figure 5 depicts didactic modules and their leader, contributors and interested. As can be seen, last three modules responsibility assignation is done in a different way. Phoenix Contact (an automation company that participates as a partner via EduNet World Association e.V.) takes charge of M9, because they are created PLCnext technology. ETAT Smart Lab equipment module (M10) is assigned to the partners in charge of the Working Package 4, because this was part of their tasks. As the Process Models are different for each partner, each one develops its own didactic module (M11).

		Hours					Final distribution		
ID	Comments	THEO (D3.4)	PRAC (D3.5)	THEO hours	PRAC hours	Total of Hours	LEADER	Contributor	Interested
M1	Includes OPC, OPC UA, MES	12	9	75	79	154	P8-BUU	P11-KMUTNB	P9-RMUTTO
M2	PLCs and IEC 61131-3 programming	5	9				P11-KMUTNB	P10-RRU	P8-BUU
M3	Modbus, Ethernet/IP, Profinet, IO Link, Wi-Fi, Cyber security	6	10				P11-KMUTNB	P8 BUU	P9 to P13
M4	MQTT, REST API, Proficloud, Google Cloud	11	10				P13-KMITL	P8 to P13	
M5	*Only* ***Node-Red programming***	3	5				P8-BUU	P11-KMUTNB	P9, P12, P13
M6	*Only* ***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	From Phoenix Contact (PxC)	3	3	3	3	6	PxC		
M10	Outcomes from WP4	2	2	2	2	4	WP4		
M11	Each partner should prepare their own documentation	4	4	4	4	8	P8 to P13		
				84	88	172			
				THEO hours	PRAC hours	Total of Hours			

Fig. 5. Topic leader, contributors, and interested

4.5 Preparation of Didactic Modules

Core components of didactic modules include Responsible Person, Teaching Hours, Teaching Methods, Teaching Materials, and Assessment/Evaluation Methods as it is shown in Fig. 6.

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, remote labs) and assessment mechanisms.

A control list has been developed to supervise the progress of this activity. Figure 7 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.

European partners give support in this process in different ways: providing learning materials, providing access to remote labs, training the trainers (Thai teachers) and as consultants in the development of teaching material.

5 Next Steps in ETAT Project

5.1 Matching Didactic Modules and Courses

Once the didactic Modules have been defined it is necessary to match teaching units and teaching/learning mechanisms to the curriculum reference courses at each Thai university.

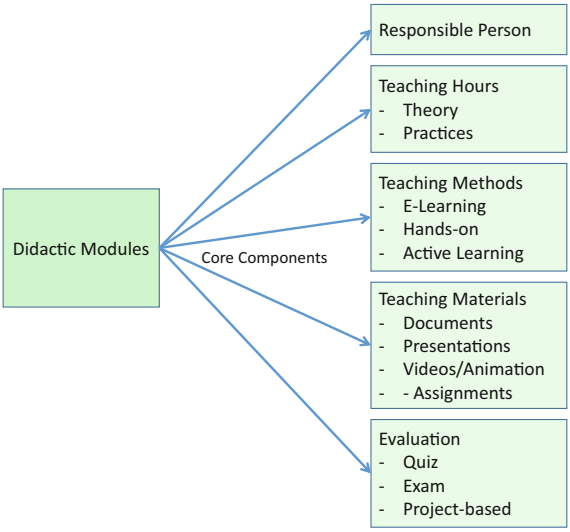

Fig. 6. Core components of the ETAT didactic modules.

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								

Fig. 7. Control list of the development of learning materials.

5.2 Deployment and Implementation of Training Activities

Learning materials created under this approach have to be deployed and implemented. They and their teaching methods will be used in the classes at Thai partners' universities.

The theoretical and practical activities can be done at the setup ETAT Smart Labs, which equipped with equipment and computers. At each Thai partner's university will be at least one ETAT Training Centre.

5.3 Validation, Quality Control and Improvement

During and after using these learning materials, the feedback will be then collect and evaluated. This is the way to ensure our teaching materials will suit the learners. Furthermore, with getting feedback regularly will help us improve the quality of the teaching materials constantly.

5.4 Training Accreditation

The outcomes of effectiveness the teaching materials will bring can be measure with a suitable training accreditation mechanism.

6 Conclusions and Outlook

In this work we present how international collaboration is an effective tool for updating curricula and developing teaching materials for Automation 4.0. The approach we propose conforms to OBE principles. It is a process that covers from data collection (needs analysis, new curricula, ESL…) to didactic module preparation. In the middle necessary topics are identified and grouped into didactic modules, which can then be used in learning courses. 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.

The next step of this work is to implement the created learning materials and collect the feedback. 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.

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