Using industrial computers to design advanced industrial informatics

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Abstract: TEMPUS is the European Union (EU) programme that supports the modernisation and reform of Higher Education (HE) and promotes institutional cooperation that involves the EU and EU's neighboring countries (PC). The PC includes Eastern Europe, Central Asia, the Western Balkans and also the Mediterranean region. The Medis Project belongs to the TEMPUS framework. The Medis project that is described in this article develops in this context.

Keywords: EU convergence for Industrial Technology curricula in non-EU countries, Advanced and Distributed Industrial Informatics Systems, Problem Based-Learning methodology.

I. INTRODUCTION

The Medis project belongs to the European framework TEMPUS project[1]. This involves the development and implementation of a methodology for developing a master of Industrial Technology in order to be able to teach in non-EU Partner Countries (PCs). It is to be implemented using the same credit system of the EU (European Credit Transfer System or ECTS). This system includes three cycles: the Degree, Master, and Doctorate, all in the subject area of Design and Development of Advanced Industrial Informatics Systems. The extra-European universities PCs are: Almaty and Pavlodar in Kazakhstan, Odessa and Kiev in Ukraine, and Petrozavodsk and St. Petersburg in the Russian Federation.

The main objective of Medis project is the design of curricula in PCs for the training of highly skilled engineers in the area of design and development of advanced and distributed industrial systems. To achieve this goal, the Medis project, have linked five European Universities, each specialised in a specific area of computerized industrial systems. Each one will create a specific learning module for designing curricula in PCs. In particular, the USTUTT University at Stuttgart-Deutschland develops the curriculum on *Microcontroller based Systems*. MDU University of Vasteras in Sweden establishes the curriculum from the point of view of the *mobile devices*. The UP College of Porto in Portugal establishes the curricula from the point of view of *Industrial Networks and Field Buses*. The TU College of Sofia in Bulgaria makes the design of the curriculum from the point of view of *Controllers and Simulators*. And the UPV in Valencia-Spain, designs the curricula from the perspective of *Industrial Informatics*.

The work at UPV comprises the design a module of *Industrial Computing* for the curriculum of the PCs using the methodology based on problem solving, *Problem-Based Learning* or "PBL" [1,2,3].

This methodology is a kind of active learning. It is based on problem solving, where students build their knowledge based on problems and situations from real life. Meanwhile, they also exercise in the process of reasoning that will use in their future professional job; evaluating and integrating the acquired knowledge to achieve professional technical expertise in their specialty. The essential feature of the PBL methodology is the use of problems as a starting point for the acquisition of new knowledge, and the concept that the student is the protagonist of their learning progress. With this method, applied to the Industrial Computing, the student is empowered to take the roll of "designer" of an *Industrial Computer Application*, and throughout the course, "designers" attain new knowledge, skills and attitudes as it happens in the day to day in an real project office. Designers must be able to analyze and deal with the proposed design of an industrial computer system, the same way they have to do during their future professional job.

One feature that distinguishes the traditional teaching against the PBL is that, in traditional teaching all the information is exposed first, and then the student will try to apply it to solve a problem. In PBL conversely, the design problem appears first, that motivates and identifies the learning needs. The student looks for the necessary and eventually returns to the problem to refine the requirements and specifications. Another feature of PBL is that allows group work. For this, the students in the theory class are divided into small groups (in our case no more than four each), and it is proposed to all the "designers" to conduct a project (which we call mini-project), as if it were a design contest, as happens in real life.

Furthermore, using this methodology the student acquires other transversal skills: oral presentation, report writing, and project cost estimation.

The Medis project comprises the development and implementation of a methodology for Masters Degrees in the area of Industrial Technology curricula for the PC's. The proposed methodology uses the European Credit Transfer System (ECTS), in the three-cycle system for the recognition of a Degree in the area of Design and Development of Advanced Industrial Informatics Systems. The Medis main objective is to prepare highly qualified engineers for the design and development of advanced and distributed Industrial Informatics Systems. The MEDIS project has been associated five technical universities in the EU. Each of them is specialized in a particular subject, with the aim to create a specific learning module. All modules have the equivalent level to the subjects taught in any Master course of Industrial Informatics in the EU.

The modules will be adapted to these five universities in the PCs: USTUTT (Stuttgart-Deutschland) will use microcontroller based systems. MDU (Vasteras-Sweden) will apply mobile devices. UP (Porto-Portugal) will provide the Industrial networks and Fieldbuses to achieve the control. TU (Sofia-Bulgaria) will design controllers and simulators. Finally, the UPV (Valencia-Spain) in Industrial Informatics.

This paper is structured as follows. Section 1 presents an introduction to Medis project. Section 2 outlines the Medis objectives and the PBL methodology. Section 3 describes the AIISM structure, or learning activities of AIISM: lectures, laboratories, seminars and mini-project. Section 4 details the contents and scheduling in the AIISM. And section 5 summarizes some conclusions.

II.   THE MEDIS UPV OBJECTIVES

The Technical University of Valencia (UPV) has a long expertise in the area of Industrial Computer Systems (IBS), not only at Degree level, but also at the level of Master and Doctorate. The *Degree of Computer Engineering and Electronic Engineering and Automation*, the Master of Computer Engineering, and PhD programs *Automation and Industrial Informatics* and *Computer Engineering*.

More precisely, the UPV work consists in adapting the PBL methodology in the curricula of Industrial Technology for the PC's. So, to achieve these objectives in the Medis-UPV project we will undertake the following settings:

- Propose the PBL methodology and develop the resources for teaching an Advanced Industrial Informatics Specialization Module (or AIISM) over an Industrial System. That is, under basic requirements on a small industrial problem, the control of a "Water Tank" (See figure 1). This is a small project, that we call the "Mini-Project". Among others, we prepare the academics resources that consist in: Lectures, Laboratories, Seminars, and the "Water Tank" project or Mini-project.

Figure-1: The Water tank.

- Analyze the curricula of the HE Institutions of the PCs to adapt and integrate the AIISM in the specific study program of each PC.

- Design training courses and perform the formation of teachers, technicians and administrative staff of the PCs.

- Implement the AIISM-PBL methodology in PC's and assists them during its deployment.

- Assess the implementation of the AIISM.

- Disseminate and exploit the results among stakeholders.

The AIISM is conveniently structured with different activities of progressive complexity to facilitate the student-designer teams to develop their projects along the course. The learning sessions will be organized in different activities: lectures, seminars, laboratories and mini-project implementation.

These activities are developed during five hours/day, one day of the week through a PBL methodology, using as a case study or the problem of the control of the "Water tank", (See Figure 1).

The control of the water tank or similar processes will be tackled by different platforms. Each of the other four EU partners has to tackle the control of this "Water Tank" using their corresponding point of view platform.

EU University	Platform
USTUTT (Stuttgart-Deutschland)	Microcontroller based Systems
MDU (Vasteras-Sweden)	Mobile Devices
UP (Porto-Portugal)	Industrial Networks and Fieldbuses
TU (Sofia-Bulgaria)	Controllers and Simulators
UPV (Valencia-Spain)	Industrial Computers

This article only relates to the course structure performed at the UPV, and proposes the PBL methodology on the topic *Industrial Informatics* [1].

III. THE LEARNING ACTIVITIES IN THE AIISM UPV

The AIISM from the UPV is conveniently structured with different activities using the point of view of the Industrial Computer, with progressive complexity to facilitate the working student teams to develop their projects along the course.

To develop the course, the students have to apply the knowledge acquired from the lectures and the laboratory practices. The proposed learning activities based on the PBL methodology are the following:

- Lectures and problems: The lecturer presents the main ideas of a lecture contents and proposes some application problems which student solves individually. This activity takes about 1 hour.

- Laboratory session: The students must solve a practical problem previously presented during the lecture. In this activity the students work in teams of 2 students. This activity takes about 1 hour and 15 minutes.

- Seminars: A panel discussion at least of 45 minutes is proposed with student teams of 4 students, consisting generally of solving a problem by means of PBL.

- Mini-project: The "students-designers" in team of 4 students, must dedicate to planning, design and develop the control system of the "Water tank". The mini-project is performed during about 2 hours. Weekly, the mini-project is advanced progressively and revised by the tutors.

It is necessary to establish for each activity a prerequisites list in order to provide the background and required skills to obtain knowledge benefits of this activity.

III.1. LECTURES

Lecture is the first step in the learning process for each of the topics in each course's module. The lecturer presents the main topics of the subject contents. It includes some application examples.

In the lecture the teacher takes different roles, ranging from the director of the project, the contractor who requests the implementation of a project for industrial computerization. From these different points of view, the teacher states with a common language without specialization the main elements and objectives are requested to the project. Whereas when he takes the role of project manager, the formulation of requirements is done at more specific professional level, using more technical language. The tutor poses a problem in every subject, and students use all kinds of resources, from the

search for components online, literature and application examples.

During a lecture, the teacher previously plans the lecture session based on their professional experience and presents the learning objectives of the session. The teacher contextualizes the subject within the module: the course and the career, based on the problems to be solved and the resources used in this kind of problems. Motivates the subject based on the importance of the problems coped by the subject. Lists and discusses the bibliographic resources that support the concepts that will be presented during the lecture and that students may use to deepen in their study. Presents the key concepts related to the subject, providing the needed details to properly understand them, and specifying the extra available resources and the learning process that students should follow to complete the knowledge's acquisition. Follows a logical order for the argumentation, so that students can acquire the knowledge progressively and uses illustrative examples to clarify the presented concepts. Verifies that students correctly understand the presented concepts and adapts the speech if needed, allowing students to ask questions about the concepts that are not clear enough and observing the students' answers to the control questions. Informs about which skills related to the lecture that will be evaluated. Tells students about the practical application of the presented concepts that will be performed later during the seminars, laboratories and mini-project, and which are related to the lecture, encouraging students to study the issue with sufficient interest.

After the lecture, keeps open communication channels with students, so they can make consultations before the next lecture if necessary. Later, the teacher should analyse the lecture session to improve their professional skills.

Previously to the lecture, the student has studied the recommended previous readings. He is receptive to the teacher's presentation and is proactive. Takes some notes to conceptualize what is being exposed to facilitate its further study, asks for concepts clarification if necessary, answers the questions the teacher addresses to the audience. After the session he should follow the learning method proposed by the teacher.

After the lecture the students will know what is the problem and its importance, how the problem is described, which available alternatives would solve it and the criteria to select an appropriate solving alternative even though they will not have yet the skills to apply the proposed methods. They will have a studying plan that will be organized in the form of a set of labs, seminars and mini-project.

Previously to the lecture the student must be informed about the prerequisites to successfully follow the lecture. If the prerequisites are not satisfied, a formation plan should be supplied.

During the lecture all the conversations in the classroom should be public, addressed to all of the members. The sequence of the lecture should be planned and predictable. The dynamics of the lecture should be attractive to the audience with short and direct explanations. The lecture should not explain all the details of the concepts of the subject, it should

give enough hints to let students autonomously complete the knowledge acquisition. The students must have the chance to formulate questions. Behavior rules must be defined to let the lecture to be productive and the corrective mechanisms should be effective and proportional. Potential distractors of the audience attention should be avoided or minimized.

III.2. LABS

The lab is the first practical exercise that students take to acquire a basic set of skills related to the topic presented in the lecture. The exercises in the labs solve specific and well-defined problems; they are guided, fully documented, and in progressively increasing complexity. The labs provide students with a set of tools and skills that can be used to solve more open problems during the seminars.

Previous to the lab session, the teacher plans the lab session based on his/her professional experience, presents the learning goals of the lab, contextualizes the lab within the subject. Motivates the practical exercise to be performed during the lab based on the importance of the problem it addresses. Lists and comments the equipment, the material and documentation resources needed to perform the lab. Describes the correct utilization of the lab equipment and warns about potential material and personal damage due to inappropriate use. Lecturer also answers student questions during the practical exercise.

During lab, the student, previously, has studied the lab documentation, and has attended the related lectures. He is receptive to the teacher's indications and is proactive. The takes notes to remember the indications and asks for concepts' clarification if necessary. Students work in teams of two students on the practical exercises of the lab. Answers the questions of the teacher related to the exercise. Later, the student should review and document the results of the practical exercises and eventually performs some extra optional exercises.

During lab, the technical assistant, previously, sets the necessary equipment for the lab in each of the workbenches based on the teacher's requests and his/her professional experience. Helps solving problems that could arise related to the equipment, power supply, communications and software, making diagnosis about the safeness and correctness operation of the equipment and replacing damaged components. Later, the technician should analyze the lab session to improve their professional skills.

After the lab the student should have acquired the skills to develop a basic data acquisition system. These skills will be useful in the next related seminars and mini-project exercises.

The student should have attended the related lecture and have read the recommended further lectures and the lab guide. Working teams of two people should have been set.

The lab should be fully documented. The lab guide should start with an introduction that remarks to the concepts of the lecture that are going to be applied in the practical exercise, the goals definition and a list of the material and documental resources that will be needed. The guide should continue with a definition of the practical activities in the following phases of progressive and increasing of complexity: introductory, reinforcement, advanced and optional. The first exercise in the introductory phase should be described step by step. The second exercise in the reinforcement should practice the same concepts and method than before but on a different set of problem data and without the help of the guide in this case.

The third exercise in the advanced phase should practice the application of the previously acquired tools, protocols and skills to solve a small sized and small complexity application problem. A fourth exercise should be defined in an optional final phase to let advanced students to consider further technical questions related to the topic of the lab. The teacher should supervise the practical exercises of the students, answering their questions, guiding them and providing enough hints to let the students find solutions by themselves. Recurrent errors and problems, and interesting student's designs during the lab should be shared with the whole group. Remote desktop sessions of the workbench computer screen could be presented on the slide projector.

III.3. SEMINARS

During the seminars the students must solve problems on the topic of the lecture. They have already exercised on related tools and procedures in the previous laboratories. The type of the activities in the seminar has to do with the application of those tools and procedures to design solutions to specific problems. These problems are manageable parts of more complex problems. The activities involve information searching over the Internet, designs and calculations. Students work in groups of 4 people, but they must explain and share their experiences with the whole group during the seminar meetings. In the seminars of the course different problems and sub-problems related to the design and programming of physical processes controllers are analysed from the perspective of the personal computer control platform studied in this modules.

The seminar starts with a teacher speech remembering about the key concepts presented during the lecture, and the proposition of several related design problems. The problems are decomposed in smaller parts, and the connections between the different sub-problems are discussed. Some of the problems are proposed to the whole group to start a debate, meanwhile other problems are proposed to be selected and solved by the different working teams during the seminar. After the investigation and design activities developed by each of the working teams the spokespeople share the obtained conclusions with the whole group and a second debate starts. The seminar ends with a resume by the teacher and the homework definition for each of the working teams that will prepare the next seminar session.

It's possible that the seminars can be split in several sessions if required by the complexity of the problems.

In the seminar, students practice the concepts presented in the related lectures and verify that these concepts have been assimilated correctly. To relate the previous concepts with

other technical concepts which are usually studied in different subjects, in a contextualized way. Acquire team-working skills. Acquire documentation and presentation skills. Acquire critical searching of information skills.

The student should have attended the related lecture and have read the further recommended readings. Working teams of four people should have been set. A balanced team is recommended with a similar level of initial knowledge for each of its members. One of the members' team will act as spokesperson.

III.4. MINI-PROJECT

During the mini-project students apply the knowledge and skills that they have acquired in the lectures, labs and seminars to develop in an integral way the controller of a physical process. The problem of the mini-project is the highest complexity problem in the course. The working teams in the mini-project are the same as in the seminars. The designs developed by the teams during the seminars are used as components of the mini-project's problem's solution. The teams can use in their own mini-projects, seminar designs that other teams have shared.

After the mini-project, the students should be able to integrate the tools and protocols practiced during the course to develop simple complexity and medium sized applications to control physical process. They should be able to document and present the mini-project process and outcome.

The students should have attended the lectures and completed the practical exercises of the labs and seminars that are related to the module of the mini-project that is going to be developed.

IV. CONTENTS AND SCHEDULING IN THE AIISM UPV

Based in the previous proposals, it is necessary to provide an adequate timeline for the development of the proposals. For example, a reasonable proposal is shown in figure 2.
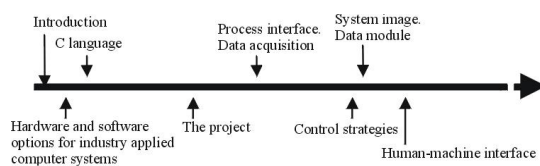

Figure 2. Proposed activities timeline

The following set of activities and time distribution in 15 weeks is proposed (See figure 3).

Chapter	Type	Topic
1	INTRODUCTION	
1	Lecture	Introduction to industrial informatics
1	Lab	Development environment - Programming the "Hello World"
1	Seminar	C programming (1) - Basic resources
1	Miniproject	Presentation of the problem to solve
1	Lecture	Structure and design of industrial informatics systems
1	Lab	Event oriented programming
1	Seminar	C programming (2) - Programming tools
1	Miniproject	Analysis of the project requirements
2	COMPUTER	
2	Lecture	Computer architecture
2	Lab	Using libraries in C
2	Seminar	C programming (3) - Libraries
2	Miniproject	Project formal specification
3	PROJECT PLANNING	
3	Lecture	Project management (1)
3	Lab	Tools for project management
3	Seminar	Discussing cases of project management systems
3	Miniproject	Project planning
4	PROGRAMMING + DATA	
4	Lecture	Modular programming
4	Lab	Modular programming in C
4	Seminar	Modular programming resources
4	Miniproject	Modular decomposition of the program
4	Lecture	Data representation and sharing
4	Lab	Data sharing between C modules
4	Seminar	Chosing the appropriate data representation
4	Miniproject	Implementation of the shared data module
5	PROCESS INTERFACE	
5	Lecture	Process interface (1) - Introduction and digital input
5	Lab	Digital input
5	Seminar	DAQ card (1) - Introduction and digital input
5	Miniproject	Implementation of the process interface module (1) - DI
5	Lecture	Process interface (2) - Digital output
5	Lab	Digital output
5	Seminar	DAQ card (2) - Digital output
5	Miniproject	Implementation of the process interface module (2) - DO
5	Lecture	Process interface (3) - Analog input and output
5	Lab	Analog input and output
5	Seminar	DAQ card (3) - Analog input and output
5	Miniproject	Implementation of the process interface module (3) - AIO
6	USER INTERFACE	
6	Lecture	Graphical user interface (1) - Introduction
6	Lab	Programming GUI controls
6	Seminar	Graphical user interface for the industry (1) - Basic
6	Miniproject	Implementation of the user interface module (1) - Basic
6	Lecture	Graphical user interface (2) - Advanced resources
6	Lab	Programming a GUI for an industrial application
6	Seminar	Graphical user interface for the industry (2) - Advanced
6	Miniproject	Implementation of the user interface module (2) - Advanced
7	TASKS	
7	Lecture	Task scheduling
7	Lab	Basic scheduler
7	Seminar	Scheduling strategies
7	Miniproject	Implementation of the task scheduler module
8	REGULATION	
8	Lecture	Foundations and continuous control
8	Lab	Programming regulation strategies (1) cc
8	Seminar	Control strategies (1) cc
8	Miniproject	Implementation of the regulator module (1) cc
8	Lecture	Event-driven control
8	Lab	Programming regulation strategies (2) edc
8	Seminar	Control strategies (2) edc
8	Miniproject	Implementation of the regulator module (2) edc
10	PROJECT (2) ENDING	
10	Lecture	Project documentation and presentation
10	Lab	Tools for project documentation
10	Seminar	Project documentation strategies
10	Miniproject	Documentation and presentation of the project

Figure 3. Lectures, Seminars, Labs and Miniproject timetable

The initial set of activities introduces two lectures about basics computer architecture and the applicability of computers to industry.

Type	Topic	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Lecture	Introduction to industrial informatics	x														
Lecture	Computer architecture		x													

The following set of activities develops skills on C programming to be applied on the application creation. This is a horizontal requirement of the module, so it is spread along the course.

Type	Topic	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Seminar	C programming basics	x	x													
Seminar	Programming tools			x												
Lab	Development environment			x												
Lab	Hello World			x												
Lab	Modular programming					x										
Lab	Data representation					x										
Lab	Event oriented programming									x						
Miniproject	Modular decomposition					x										
Seminar	Using libraries					x										
Seminar	Data sharing					x										
Miniproject	Data sharing module implementation					x										

Another basic requirement of an engineer is the correct management of a project. This is the objective of the following activities that are spread along the course. This is also a horizontal content of the module, so it is spread along the course and in a position where student understands its implications.

Type	Topic	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Seminar	Project management				x											
Miniproject	Project design				x											
Miniproject	Analysis of project specificacion				x											
Miniproject	Test and validation															x
Miniproject	Module integration														x	

The following groups of activities work with each aspect of an industrial application.

Type	Topic	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Lecture	Process interface						X									
Seminar	DAQ card National Instruments USB-6008						X	X								
Lab	Digital input						X									
Lab	Digital output							X								
Lab	Analog output								X							
Lab	Analog input								X							
Miniproject	Process interface implementation							X	X							

Figure 4: DAQ card NI USB-6008

The first set of activities deals with the connection of the computer to the real world, the so called "process interface" via DAQ card (See figure 4). This tends to motivate the student because they see the interaction with physical reality.

Taking into consideration that the actual student generation is accustomed to stunning visual user interfaces, this is the moment for introducing another motivating set of activities related to this aspect. (See figure 5).

At this point, it is necessary to start coordinating actions inside the application. So the next set of activities introduces the very basics around task coordination/scheduling.

Type	Topic	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Lecture	Task schedulling										X					
Lab	Basic scheduler										X					
Miniproject	Task schedulling implementation										X					

And, finally, the student needs to see that your development works. From the point of view of the teacher, it is adequate to introduce here the regulation problem according to the following activities.

Type	Topic	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Lecture	Regulation													X		
Seminar	Regulattion approaches													X		
Miniproject	Regulation strategy implementation													X		

V. CONCLUSIONS

This article shows some of the characteristics of the European Project Medis as part of the project TEMPUS. In particular, the paper presents the structure of Advanced Industrial Specialization Technology Module (AIISM) proposed by the Polytechnic University of Valencia (UPV). We are working in collaboration with four European universities to adapt to the model of European Credit Transfer System (ECTS), the curricula of some non-European countries and create an equivalent master in these PCs countries. We also discussed different learning activities based on PBL methodology, and focussed at a design problem of a particular industrial computer application: *The Water Tank*. It has been developed at UPV for the creation of master classes, laboratories, seminars and mini-project. The four other US universities address this same problem from the point of view of their subject.

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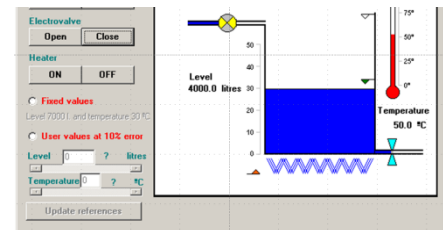
Type	Topic	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Lecture	Graphical user interface											X				
Seminar	Graphical user interface for the industry											X				
Lab	A GUI for an industrial applications												X			
Miniproject	User interface implementation												X	X		

Figure 5: GUI for the "Water tank"