New Teaching Approaches in Embedded System Courses

Dirk Van Merode [1], Galyna Tabunshchyk [2], Peter Arras[3], Karsten Henke[4]

[1] Msc, Research Engineer EmSys, Thomas More Mechelen-Antwerpen, Belgium, dirk.vanmerode@thomasmore.be
[2] PhD, Assoc. Prof., Zaporizhzhya National Technical University, Ukraine, galina.tabunshchik@gmail.com
[3] Dr. ing., International Relations Officer, KU Leuven – faculty of engineering technology, Belgium, peter.arras@kuleuven.be
[4] Dr.-Ing., Professor, Ilmenau University of Technology - Integrated Communication Systems Group, Ilmenau, Germany, karsten.henke@tu-ilmenau.de

Abstract— **This article highlights new teaching approaches and course development in the field of embedded systems, within an international European Tempus project with a consortium of higher educational institutes from the EU and partners in Ukraine, Georgia and Armenia. It considers lessons learned and sharing of best practices within the development of concurrent courses and modules and implementing them in the partner universities. Considerable effort is attributed to strengthen the ties with industry in the field of embedded systems. The paper elaborates on the scope of the project, preliminary analysis of competences needed for the local and international labor market, the intended goals of the project and strategies used in quality, dissemination and management of the project. In detail it deals with the courses developed, thematically divided in courses for hardware, software, CAD/CAM/CAE and labor market skills, all with learning disabilities in mind, ways to train the teachers on the new material and ways to support students with the newly delivered equipment. All is done in a blended learning way, with the use of distance learning, hands-on, remote and virtual laboratories. Finally this article deals with the risks and challenges of international projects of this scope and intermediary results.**

Keywords— Embedded systems, education, Tempus projects, quality assurance

I. INTRODUCTION

To teach courses in embedded systems design and production demands a very specific, qualitative and valuable knowledge growth in target Higher Educational Institutes (HEIs), which ensures efficient implementation of high-skilled people in the labor market. To keep this knowledge relevant for the local and international labor market, universities should strengthen their links with industry, working in this field.

This project 544091-TEMPUS-1-2013-1-BE-TEMPUS-JPCR "Development of Embedded System Courses with implementation of Innovative Virtual approaches for integration of Research, Education and Production in UA, GE, AM" [DesIRE] means to bring all partners HEI's involved up-to-speed with modern tools and embedded platforms and develop a working relationship with local industry.

The goal is to develop relevant and up-to-date course material, deliver supporting hardware for a physical embedded systems laboratory, virtual and remote laboratories, to train the teachers both in the EU and at their own home institution and run a pilot teaching period with the new material to assess the results. All this is done with an elaborate quality scheme, decent management and with ample dissemination of the intermediate and final results.

Figure 1: The DesIRE logo

II. THE SCOPE OF THE DESIRE PROJECT

The consortium of EU universities consists of Thomas More Mechelen-Antwerpen University College (TMMA), Ilmenau University of Technology (IUT), Constantine the Philosopher University in Nitra (UKF) providing a mutual practical-oriented approach in teaching in the sphere of embedded system. All bring in specific expertise in the project. TMMA will provide courses and deliver lab-infrastructure for embedded software and CAD/CAM/CAE, IUT will focus on embedded hardware, remote and virtual laboratories, UKF will highlight the pedagogical side on teaching engineering courses, quality assurance and transferable skills.

Different modules and courses were planned, which combine all approaches.

A first module, "Hardware for Embedded Systems"(9 ECTS), consists of theoretical courses supported with practical exercises on the new equipment. In this module there are courses on Microcontrollers; Digital Electronics; Digital System Design; Embedded Communication; Sensors, Actuators and Interfacing.

A second module, "Software for Embedded Systems" (11 ECTS), also with theory and practical exercises, has the following courses: C for Embedded Systems; Embedded Software Development; Embedded Operating Systems; GUI development; Multicore Programming; Software Testing.

The third Module, „CAD/CAM/CAE for Embedded Systems", (6 ECTS) considers ECAD, electronic design and MCAD, mechanical design.

Seven additional courses are conceived: Digital Signal Processing (2 ECTS); Remote Labs and Virtualization (3.5 ECTS; Legislation on and Certification of Embedded End-Products (1 ECTS); Management and Marketing of Embedded End-Products (2 ECTS); Quality Engineering (2.5 ECTS); New teaching approaches in Engineering (1,5 ECTS); Soft Skills for engineers (1,5 ECTS).

The strategy for equipment purchase is to provide a mixture of hands-on laboratories, combined with remote and virtual laboratories and supportive equipment, such as PCs, servers and network equipment to run the necessary software on.

III. ANALYSIS OF THE CURRENT SITUTION IN UA, GE AM

According to the project plan, analyses of current curricula and competences expected at the labor market in Embedded Systems were conducted in target countries (TC) in the period from March to May 2014. These surveys both address students and staff of the target HEIs and local labor market. The outcomes were synthesized and each partner presented a detailed report. Analyses of the reports can be summarized as follows:

- all universities in each partner country (Georgia, Armenia and the Ukraine) decided to closely collaborate;
- each partner university has the necessary human, educational, informational and logistical support for a high-quality preparation of students in the field of ES;
- teachers organize the educational process to be aimed at the implementation of specific objectives of educational reforms and the Bologna process;
- analyses of the labor market show the importance of preparation of specialists in embedded systems;
- university students are familiar with contemporary approaches in education, however, they are rarely used, and, in general, virtual labs are more known than remote experiments.
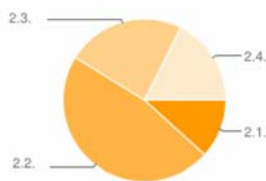

2.1. Professionals enough.
2.2. There is a definite need in additional specialists.
2.3. Almost no specialists.
2.4. Hard to say.

Figure 2: Embedded systems professionals in Kyiv region

IV. RE-USABLE MODULES AND BLENDED LEARNING

To organize an overall conception of teaching in the field of Embedded systems responsibilities for the modules and courses were distribute between EU partners:

- Thomas More Mechelen-Antwerpen University College (TMMA)
- Ilmenau University of Technology (IUT)
- Constantine the Philosopher University in Nitra (UKF)

For all course material developed, a dedicated syllabus was made, at an early stage in the project. This syllabus gives an overview of topics, ECTS, assessment, learning outcomes envisaged and teaching methods. This is needed for the target universities to plan implementation of the new material in the existing curricula, to give substituted courses or to upgrade content.

For the development of the corresponding course material, some lay-out rules and an inter-active Word-template, with auto-text features, is drawn up. This ensures uniformity, readability and accessibility for people with learning disabilities, such as visual function limitation attention deficit disorder (ADD) autism spectrum disorder (ASD).

Figure 3: Course template

For efficient learning, new equipment is provided both for hands on training, the so-called Embedded Systems Design Lab, and for remote and virtual training, the Goldi Remote Lab. The target HEIs received the state-of-the-art equipment to support the teaching material, with additional PCs, network and server equipment for the use of the CAD and other software needed. The goal is to give access to the students at both the hands-on lab and the remote and virtual labs. But partners are also urged to give access to third parties, like colleges and secondary schools, who will deliver new students in the future and to local industry, who can benefit from new and interesting platforms to develop on. Another project's outcome is to have in all universities the same kind of equipment, to enable future mutual work and sharing of good practices. All equipment is also selected for its relevance to the subjects of the course material and to industry-standards.

In each university 8 set-ups are provided, with one PC and five different embedded systems.
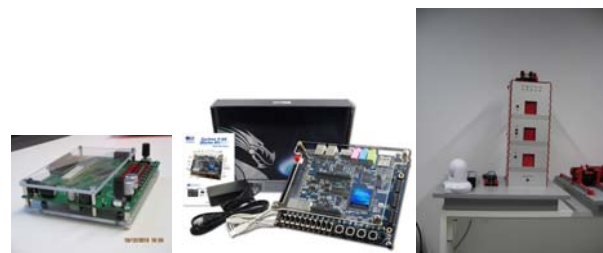

Figure 4: Embedded Systems

In addition, two universities invested in a low-entry robot system, to teach youngsters the principles of embedded programming, to make them enthusiastic about STEM.

Other universities allocated some of their budget to a 3D printer, to support the work in CAD-systems and to completely close the loop to a functional prototype of an actual product.
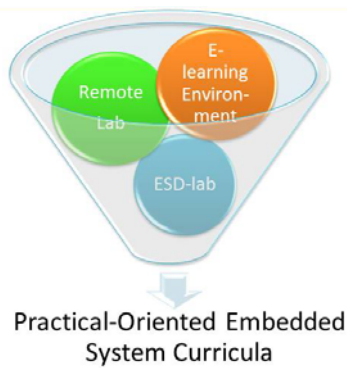

Practical-Oriented Embedded
System Curricula

Figure 5: ES Laboratories

Moodle is implemented as a learning management system and the two pedagogical universities in the consortium provided dedicated training on this system.

Figure 6: Blended learning

V. RISKS AND CHALLENGES OF MULTINATIONAL PROJECT

The different working bodies in the project are the Project Management Team, which is the strategic decision-making body, consisting of one member from all partners. They communicate regularly and each year progress meeting are organized to define the strategy for the upcoming period. The Local Project Team is responsible for the implementation at the institutional level. The Daily Management Board takes care of the day-to-day business of the project, short-term planning and actions, the Project Quality Manager (PQM) is responsible for the quality of the project, sends out surveys, both timely based and event based. The PQM is supported for his or her work by Institutional Quality Manager (IQM) and Country Quality Managers (CQM) for each country involved in the project.

For risk definition and mitigation, the Quality Managers are of key importance, because they are responsible for risk definition, assessment and mitigation plans. Quality however is the task of all involved and the resolution of risks and conflicts should be done by people directly involved.

The LPTs support the grant holder, DMB and PMT with their work: they deliver the reports which describe the work done and they make up and use questionnaires for quality evaluation of the actions. Next to reporting, the LPTs are responsible for the communication and handling the project according to the local national rules. They take care of the registration of the project in the national offices/ministries. They search local dealers for equipment and – if necessary – look for brokers to help the administrative process of getting equipment to the partners. They support the grant holder with their own experiences and lessons learned from previous and similar projects.
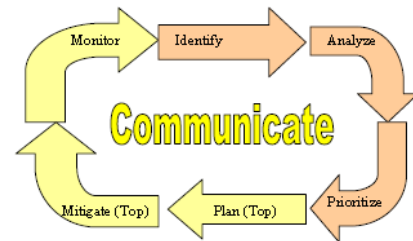

Figure 7: Risk management cycle

In the project there are different levels of Quality Management to be defined, with the associated risks resulting from this.

The first level is the risks on project level, the second level is the international level, for the third level we look at national level and the last one is the institutional level. They should be prioritized in this manner, as they have a more or less severe influence in achieving the project goals.

On the project level, risks have to do with the project management and smooth rollout of all the different processes. Some examples of risks on this level are: not meeting up to funding agency's standards, insufficient budgeting, and late expenditure of budgets, discrepancies in accountancy system, the lack of proper management, unsolvable differences between partners, and lack of proper document follow-up. It is clear that these risks can lead to total or partial project failure. The partners involved should be well aware of these risks and be very punctual in following the work plan and delivering all necessary documents, to avoid loss of time or, even worse, making some cost ineligible, resulting in the loss of budget.

The international level is important as it governs the relations between the different countries. This can be on a political level or on an international trading level. This mainly governs the relations between EU and target countries. An unfortunate example is the obligatory suspension of a partner from Crimea, due to the illegal annexation by Russia of the peninsula.

Less profound impact on the project outcomes are trading limitations. It is the case that no taxes whatsoever can be raised on the important goods in the frame of these European projects. But importing equipment in Ukraine is virtually impossible without the service of a customs broker, which augments the cost. This is budgeted for upfront, so this is not a big difficulty for the project's outcomes and results, but better not to forget this is project preparation. Of course this administrative burden has its effect on the project outcome in the extent that it is the goal to deliver the goods to all universities involved, but this does not jeopardize the whole project as such. It could be argued that the ease of administration will prove to be

beneficial for the national universities and that the lack of good will in this matter, could result in universities not getting the equipment for supporting the courses developed.

Of course currency changes also have their impact on the easy of importing and exporting goods to and from the different countries.

When we consider the national level, the biggest obstacle for smooth project roll-out is the political instability in Ukraine. The main goal of the project management is to attribute the appropriate budget to staff members in the target universities who take up an active role in the project and make sure all equipment foreseen can be put into use, where it is needed. The fluctuating currency course of the Hryvnia compared to the Euro and the uncertainty in future outcome of the conflict and day to day change in events and regulations, makes the financial part of the project, payments for mobility and staff costs, very hard. In agreement with the partners and university's management, it is decided that the project works with cash payments upon signing of a cash receipt. This induces a very big administrative burden, because all people involved need a personal accountancy, which is not budgeted for in the original proposal. There is also the issue of security and liability when transporting big amount in cash to different meetings. On the other hand, it is the project's management belief that this extra work is small compared to the huge help this is for all staff in Ukraine who work hard to make the project work in difficult circumstances. Another effect of the deteriorated relationship between the EU and Russia, that it is very difficult for DSEA, in Kramatorsk, to develop the UEGC, i.e. cooperation with local industry, under the European flag. Cooperation is initiated, and existing, but of course, business leaders need to keep their personal integrity and the one of their firm in mind.

Another important issue is the support of local government. It is government that needs to allow registration of the project, to be able to be compliant of EU rules.

The last level is the institutional level. It is important that all necessary measures for local project implementation should be taken. To be precise, this means providing people with time to do their assigned work in the project, to provide rooms for laboratory set up, to be willing to implement new courses in the existing curriculum. Personal ambition, self-rewarding travels, historical competition or reluctance to cooperate between different departments could damage useful project results.

To cope with risks, at all levels the Quality Assurance and Control Plan is made. Actually risks are considered in relation to the project goals, as risks threaten these outcomes. Also an list of the institutional responsible people for quality is given and a timely overview on the deliverables needed.

Another very important tool for risk management within the DESIRE project is the local project plan. This is there to both work with centralized and de-centralized management of the project.

In this project plan first a list of key persons is given, their role in the HEI and their role in the project. This is important as a feed–back to have a good overview on the people involved and changes to the Local Project Team. It also gives insight on whom to contact for specific questions.

Second local actions in each work package is defined, with a proper timing, associated deliverables, key performance indicators, possible treats in the work package and treat resolution. This is a valuable source of information for local project implementation and for the Project Coordinator and the Project Quality Manager to base the quality strategy upon and to define curative measures.

Keeping timing is crucial on all levels, not to lose track of time and necessary outcomes. Administration has a huge repercussion on the project outcomes. In a project of this magnitude up to a couple of 100 staff members and stakeholders (students, members of industry, HEI management, local government) are involved and all should be very punctual on filling in and delivering all supporting documents.

VI. CONCLUSIONS

Devising and running a multi-national project is a challenge. Especially the introduction of new teaching techniques and new methods of collaboration with industry and other stakeholders is the hardest part in running the project successfully as in the pedagogical tradition of the target countries these are completely new and unknown aspects.

In general all planned actions are running as expected. A survey is performed to assess the regional needs by the target partners, courses are developed accordingly, a list of equipment needed is drafted and the delivery of these learning aids is almost finished. The staff of the targeted partners is trained in the EU, demo sessions and pilot teaching is planned in the second half of the project runtime.

No major threats to the overall project outcomes can be defined at this moment. In all work packages the necessary work is done in a timely and satisfactory manner. So the quality monitoring is clearly visible in the project's results.

There are some difficulties encountered so far, which are resolved, but has had repercussions on the workload for people involved. First there is the timely delivery of all the course material, where some of the more specialized course content is facing some delay. Second the political destabilization of Ukraine has its effect on the accountancy of the project. Third import regulations in some of the targeted countries are burdensome and this bureaucracy definitely limits the dynamics of the delivery process.

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