Training Microsystems Technologies in an European eLearning Environment

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Abstract—**The paper presents the ongoing activities within an European project for development of eLearning courses in microsystem technologies. It is a two-year project within the Leonardo da Vinci programme and the partners are from small and medium enterprises in microelectronics, training organizations and universities from four European countries – Romania, Bulgaria, France and Germany. The project is aimed at implementation of innovative approaches for performance–centred learning and development of new instruments in instructional design of task-performance-centred courses for education in Microsystems design and technology.**

Keywords-Microsystems technology education, performance-centred approach; e-learning, European project

I. INTRODUCTION

Scientific research, technological development and innovation are at the heart of the knowledge-based economy, a key factor in growth, the competitiveness of companies and employment [1]. "The shift to a knowledge based economy is of crucial importance to competitiveness and growth. Business and citizens in the EU have been slower in embracing this new economy than in the United States. The Lisbon indicators confirm that investment in the development and introduction of new technologies is behind the United States." [2] Micro- and today nanoelectronics is the most rapidly developing science. All specialists in the field need regular re-training. In this most rapidly developing science which represents the basis of the e-economy and the e-society the continuous training is crucial.

The shortage of engineers in micro- nanosystems and the systematic decrease of students in electronics at the university can be a threat to the European economy competitiveness. The informal Meeting of Ministers of Education and Ministers of Research in Uppsala underlined the importance of increasing recruitment to scientific and technological disciplines, including a general renewal of pedagogy and closer links to working life and industry throughout the whole educational and training system [3]. In many publications at the 3rd European workshop "Microelectronics Education" it was stated that "a new breed of engineers must be created and the way we create them has to change" [4] "from the classical engineering schools to multi-disciplinary research organisation - system design centres". So, a partnership between small and medium enterprises (SME) and universities for delivering training in Microsystems technology has crucial importance for the European competitiveness on the world market for electronic systems.

Additionally, it is important to be mentioned that Europe's electronics industry is increasingly moving east. Multinational OEM (Original Equipment Manufacturer) and EMS (Electronics Manufacturing Services, contract manufacturers) companies invested great amount of capital and built up high-tech plants in Romania during the last years. The reasons why Romania is an ideal investment location in Europe include, first of all, their well-trained, creative and flexible human capital, in particular highly educated engineers and skilled workers, accompanied by high productivity/wage ratio. Based on mSysTech project, the Romanian working force involved in micro-systems and related fields will have the opportunity to be in contact with the latest developments in these very dynamic fields and to have access to practice oriented, vocational training courses destined to the knowledge level.

Bulgaria has also strong traditions in microelectronics (in 1989 the foundry in Botevgrad worked on a technology of 2 µm which was the top technology at that time) and the last 5 years a number of new SMEs in the field are created (HIC, EPIQ, Milexis, Centillion, NanoToolShop, etc.) and MSysTech project is designed to meet their needs of qualified and trained personnel.

II. RATIONAL OF THE PROJECT

In the 21st century the high level research is increasingly complex and interdisciplinary; it is increasingly costly; high level research requires a constantly increasing "critical mass". Microsystems are developing on highest level of research and the continuous training is crucial. This project is aimed at adapting the existing and developing new courses for the lifelong performance support systems in microelectronic packaging and microsystems for the needs of the Romanian and Bulgarian SMEs, vocational schools and universities.

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There are very few individual research teams or laboratories or companies that can reasonably claim to be able to respond to the technological challenges. In nano-era an integrated approach is needed, and interaction of innovative SMEs, universities and research organisations in the research and training actions and it is a key factor for strengthening the European RTD potential. The Internet courses within the mSysTech project will provide new opportunities for co-operation between vocational training institutions, universities and SMEs in the sharing of knowledge and educational resources: the distributed support system in four European countries created in the IPCI project will be enlarged with two new countries within the proposed project.

III. OBJECTIVES

This project is aimed at adapting and integrating innovative performance-centred training approach into engineering education and training organisations and SMEs in microsystems technologies. The focus is on the transfer of innovation in two new countries: Romania and Bulgaria and in the multidisciplinary area of microsystems. Its objectives are:

– identifying and analysing user requirements of managers, engineers, students and technical staff in the multidisciplinary science of microsystems technologies,

– selecting ICT-based innovative content to meet these requirements and analysing the feasibility of transfer of the performance-centred approach to train this content,

– adapting and implementing the e-learning environment with training materials with simulations, demonstrations to improve skills in microsystem technology.

– training the core user groups of training providers – teachers, managers and educational policy makers in the innovative learning approaches and in the effective collaborative use of new technologies in vocational education and training.

The primary target groups concerned are: students in engineering education and vocational schools, professionals from SME in electronics and Microsystems, educated but unemployed people (e.g. engineers, physicists) looking for additional training for employment.

IV. IMPLEMENTATION

The mSysTech project is based on the positive results and experiences in two European pilot projects: Leonardo da Vinci project “Internet-based Performance Centred Instruction – the Link between Work and Education” (IPCI) and Socrates/Minerva “On-line Learning Mathematics and Sciences”.

Within the IPCI project a complete set of courses covering microelectronics design, technology and packaging were developed. There are not many frameworks that unify these subjects in an attractive way. The performance centred approach has been proven to be more effective than the traditional lecture-practice-test (expository inductive) in training higher order skills, for preparing learners for self-learning, improving, adapting for changing tasks, jobs.

In mSysTech the performance-centred job-linked training approach will be used also and the selected content from the courses of IPCI will be adapted and up-dated for the needs of Romanian and Bulgarian electronic sector and education. The new learning materials on the Microsystems technology and the evolution of nanosystems during the last three years (after the end of IPCI) will be developed and used by all partners in the project, as well by the partners from the IPCI project who are not in the mSysTech partnership.

The project main result will be an e-learning environment with innovative pedagogical approach and the use of state-of-the-art multimedia materials to train the newest technological achievements in the sciences representing the basis of the e-Europe. It will provide performance support to the individuals undertaking self-directed learning.

The following courses are already developed:

- *Microsystems Design and Technology* by Institut National Polytechnique Grenoble, Centre interuniversitaire de microélectronique, NanoTech.

The objective of the course is to show the physical background and the approaches that are used in the design of MEMS-based sensors and actuators. The course gives an overview of microsystem technology and its applications. The course suits especially well for students who aim for R&D tasks. Following issues are discussed using examples of different MEMS devices design:

• Modelling and simulation of MEMS devices

• Different types of transduction processes used in MEMS

• MEMS based accelerometers

• MEMS based pressure sensors.

- *Packaging Technologies* by Politehnica" University of Bucharest, Center for Technological Electronics and Interconnection Techniques (Fig. 1).

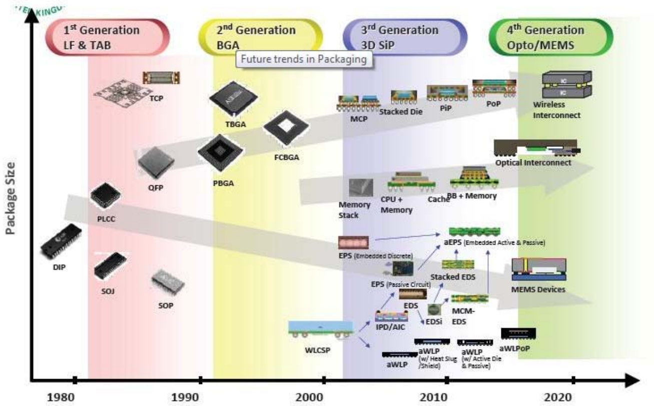

Figure 1. One image from the “Packaging Technologies” course

The objective of the course is to introduce the learners in microsystems packaging technologies, including design, analysis, fabrication, assembling, characterization and testing. In addition, this course introduces the most recent developments of micro-/nanofabrication technologies. The course covers the research and innovation in the following major topics:

• Fundamentals of microsystems packaging;

• Packaging Materials;

• Electronic design, CAE-CAD-CAM and EDA of microelectronic systems;

• Modelling and simulation of electronic/microelectronic structures;

• Assembling technologies based on RoHS & WEEE European Directives;

• Measurement, characterization and testing of microsystems.

- *Thermal Management of Microsystems* by the Technical University of Sofia, Department of Microelectronics.

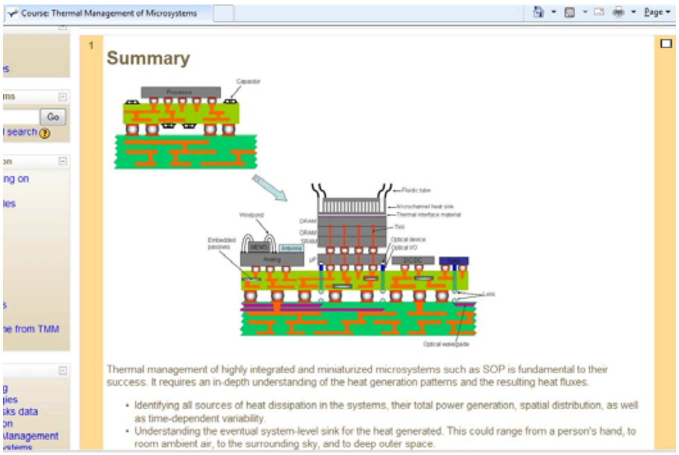

Figure 2. The "Summary" screen of the course "Thermal Management of Microsystems"

This course deals with effective thermal management of highly miniaturized system-on-package (SOP)-based systems (Fig. 2). The learners will be able to define the most appropriate method of design and packaging of different microsystems for effective heat evacuation and minimisation of the hot spot effect; to evaluate the reliability and to identify the possible defaults dues to overheating in order to insure the reliable functioning of the microsystem. The course covers the following major topics:

• fundamentals of thermal management of mycrosystems;

• thermal sources in systems on package (digital SOP, RF SOP, Optoelectronic SOP, MEMS);

• fundamental heat transfer modes;

• thermal characterisation: numerical methods for thermal characterisation; evaluation of thermal analysis software for Microsystems; experimental methods for thermal characterisation;

• thermal management technologies: passive methods of thermal management (high-conductivity package materials, thermal vias, heat spreader, extended surfaces, heat pipes [5]); active methods of thermal management (liquid loops, spray cooling, thermosyphon, thermoelectric cooling, thermionic cooling etc.);

• power minimisation technologies.

- *Photomasks Data Preparation* by Xyalis Ltd, Grenoble.

Main goal of this course is to present the techniques used in micro- and nanocomponents photomask data preparation. This course will allow to fully understand all the issues related to this critical step of chip development as well as the methods used to reduce both costs and delays. The course introduces the basics of photolithography and the various types of masks used. A detailed description of the multiple constraints and of all the patterns required on masks is provided:

• process control modules

• measurement structures

• alignment marks

• identification patterns

• chips

The different steps of mask data preparation will be explained:

• input data manipulation, validation, fracturing, OPC (optical Proximity Correction)

• assembly of various devices

• constraints and optimization

• inspection techniques

• repair techniques.

Figure 3. The module on MEMS mask data preparation

MEMS related issues are detailed (Fig. 3). The last module gives an overview of advanced research and state of the art in photomask development.

The courses available on Internet will improve the accessibility of the learning materials and the delivery of training in all contexts: at home, in the university or vocational school, and the most important - on-the-job.

V. The Approach

Focusing on learning or knowledge transfer rather than performance results in people who know what to do but never do it [6]. Learning technologists must recognize that their jobs do not end with training. Learning must be turned into performance, shared with the entire organization, then cycled back into the next iteration of training. Learning technologists must take an interest in - if not responsibility for - the full cycle. They need to embed performance support and knowledge sharing into learning activities so they become second nature to the learners/performers.

So, in our project we decided not just to design an improved training but to perform a performance-centred design. The performance-centred design transforms knowledge into performance by creating an interface to the knowledge base. In the design we followed the principles, determined by Rosenberg [7].

Performer-Centred Design. A key difference between performance support systems and training systems is the locus of control. In training systems, the author takes the role of expert and sets the rules for working and the criteria for success. In a performance support system, we must recognize the performer's expertise in his/her environment and the fact that the performer may have additional information not contained within or considered by the support system. Our system, therefore, takes the role of an assistant rather than a director.

Learn by doing. Much of what we know to do in a job we learn on the job. One of the responses of the training community has been to provide just-in-time training or on-demand learning, so as to situate the training in the job environment at the time of need. This direction has great merit and no doubt will benefit development of work competencies, but I suspect that the greatest limitation of training is its abstractness. Merely changing the time and place will not make it contextually appropriate. Our learning and support systems need to increasingly model apprenticeships rather than simply serve as information distribution systems.

Apprenticeships embed the learning of skills in their social and functional context and make the "what is learned" more meaningful and valuable. A performance support system should encourage workers to try things that stretch their knowledge and skills.

Organizational Memory. Organizational memory refers to the knowledge that an organization has or could have about its business and to the process it uses to acquire and recall that knowledge. It includes what is archived in electronic and paper documents, but even more critically, what people in doing their work have learned. How often have we been in a situation where we need to know something and instead of looking it up in books or other archives—we call someone?

Our support systems should aspire to mimic the knowledge base and process for acquiring expertise that is used by practitioners. Thus, the process needs to be on-going, rooted in practice and experience, and constantly adjusted by new inputs. We need to find ways to capture and share expertise. So, in the reported Web-based performance support system the knowledge base is the core component.

Technology Use. The performance support system (PSS) is a natural extension of building technologies that transform the way people work and learn. The technologies of performance support help people be connected when they are mobile [8], be competent when they are inexperienced, be reflective when they are hurried, and be resourceful when they are challenged. Our system is Web-based.

VI. How Instruction in PSS is Different from Traditional Computer-Based Training

Computer-Based Training (CBT) systems are often set up to enforce the sequencing of sections determined by the task analysis [9]. The enforcing of the sequencing relies on the system keeping learner's records. The system checks the learner's record to determine if the learner has completed the required prerequisite sections satisfactorily before allowing the learner to enter a new section of the lesson.

In PSS enforcing the viewing of prerequisite is not present. It is up to the learners to determine if they need to review the prerequisites. Links to the prerequisites are provided, but viewing them is not mandatory.

Learner's records should not be kept, if at all possible. One of the main purposes for keeping learner's records is to enforce the sequencing of instruction. Because the learners choose their own sequence in PSS, there is no need to keep learner's records for sequencing purposes.

Lesson segments are as small as possible. In PSS, the learners usually enter the instructional component to learn a specific task. The lesson segment should only cover that specific task. If the lesson component covers more information, the learner takes longer to complete the original task.

Lesson segments are self contained. The instructional developer should try to limit the dependence on other lesson segments, because there is no guarantee that the learner has viewed the other lesson segments. The instructional developer should try to minimize any undefined acronyms and backward reference.

It is easy for the learner to use the instructional component. We don't make the learner sign in to the instructional component, and we allow the learner to escape from the training at any point.

The primary targets groups of mSysTech system are the students in engineering education and colleges, who need education related to their further work, learning competencies necessary for the workers in an 'intelligent organization'. So, the instruction in the training modules is designed following the PSS technology.

VII. Project Outcomes and Innovation

The main expected outcomes of the project are:

- System for on-line course development with a performance support system (PSS) for developers;
- Virtual Performance Centred Environment for Training in Micro- and nanoelectrinics, and Microsystems technology;
- Training materials for 3 courses in microsystem design and technology, packaging and thermal management; Internet-based tutorials;
- Database to facilitate access to training and professional realisation of women in the sector of micro- and nanoelectronics, and microsystems and to provide equal opportunities for women and men.

The innovation contributed by this project involves:

- new approaches to the use of existing methods: distributed performance support system

The project considers the concept of a performance support system from a new theoretical perspective in where distributed cognition and distributed learning are underlying concepts. Learners have opportunity to interact not only with particular content but also with peers, instructors and other experts.

- new products in response to existing problems: training courses in Microsystems technology

The courses are developed in response to the training needs described above.

- new processes: distributed learning

Distributed learning rather provides new perspective and dimensions of the classical distance learning concept. *Distributed learning* in the context of PSS does not ignore the importance of organising learning content and its sequence, but emphasises on creating a learning environment that enables an interaction with learning resources, peers, instructors, and external experts, located at different places, with no time constraints. Learners gain a greater control on constructing their learning. Distributed learning changes the role of the instructor from knowledge transmitter to coach or facilitator.

- new forms of co-operation between partner organisations: distributed curriculum.

The idea for distributed curriculum or a Virtual Technical University is not so novel. For example in USA the National Technological University is providing distance engineering education with distributed curricula, i.e. the departments from different universities which are the best in some area develop the corresponding course and it is delivered in a common curriculum in one virtual university.

In the proposed project we will apply the same approach in the development and delivery of the distributed curriculum in microsystems with the difference that we will involve not only training organisations but the main users as developers – the SMEs. The notion of distributed PSS introduces the concept of *distributed instruction* as well. It applies embedded content management facilities with tools, templates, and guidelines for designing courses from reusable learning objects in a shared repository. The *mSysTech* is an open course initiative with an attempt to build a case of good practice based on the collected experience.

VIII. Summary and Conclusion

In this manuscript we presented a work in progress within the European Community project "e-Training Microsystems Technologies". The project is aimed at implementation of innovative approaches for performance–centred learning and development of new instruments in instructional design of task-performance-centred courses for training in microsystems. At this stage in the project lifecycle we have already developed the IPCI environment with its main components, and with an integrated environment for the training materials development. Four courses are being designed and the learning materials of three courses are under development by the teachers.

As a new technology, IPCI will move the traditional teaching systems to the closely related to the job learning. In this point, these systems have a strong potential to help students mastering job-related skills. The message to the teachers, to consider the impact of teaching on results, good performance and competitiveness, is another perspective of this innovation.

As happens with most new technologies, some people will promote PSSs as the answer to all problems. But like most technologies, PSS has its limitations. If the improvement in employee's performance in corporate setting thanks to the PSS is already proved, for the students there are some doubts and we have to study the effectiveness of this approach in the university context. And we expect to learn more about the effectiveness of this approach through experiment planned for the pilot test.

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