AN EUROPEAN PROJECT ON WEB-BASED EDUCATION IN NANOELECTRONICS

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ABSTRACT

The NanoSkills project is intended to support the development of sectoral qualifications system and frameworks by definition of qualifications of engineers and technicians in nanotechnologies in terms of learning outcomes to promote transparency and recognition of vocational education and training (VET).

The project brings together VET providers, higher education (HE) institutions, small and medium enterprises, professional organisations to assess future skills needs and promote business input into course design, as stated in the "New Skills for New Jobs" initiative and to develop special courses for upgrading knowledge in the sector of nanoelectronics technologies. Through job analysis the necessary knowledge, skills and competences in nanotechnology engineering were defined. Nine courses are designed by the best laboratory/department in the field which dispose with the necessary infrastructure and facilities for practical work.

These are e-learning courses and m-learning performance support modules. Tests of the ECVET application to VET qualifications and recommendations how to enhance permeability and progression between VET and practice-oriented HE will be done during the pilot test.

KEY WORDS
Academia/industry collaboration on Web-based training, nano-electronics, sectoral qualifications system, credit system, vocational education and training, higher education, ECVET.

1. Introduction

The multidisciplinary science of nanoelectronics is just emerging. There is a need of re-training of personnel in the enterprises and education of young specialists for the sector and a collaborative development approach will provide the most effective training.

Nanoelectronics is developing on highest level of research. In this most rapidly developing science which represents the ground of the e-economy and the e-society the continuous training is crucial [1]. There are very few individual research teams or laboratories or companies that can reasonably claim to be able to respond to these challenges.

In nano-era an integrated approach is needed. The interaction of innovative SMEs, universities and research organisations in the research and training actions is a key factor for strengthening the European RTD potential [2].

In the last five years, the project partners have been working on applying performance-centered methodology in university education, training and vocational education starting with IPSS_EE Minerva project [3], and then continuing with DIPSEIL [4] and IPLECS projects [5]. In the presented project, based on our previous experiences, we adapt the approach of the big enterprises in the sector to share the research and development facilities and expertise despite the competition (or just to be competitive).

2. Needs of Change

The preliminary need analysis related to the sector of micro- nanoelectronics was summarised in the introduction. Here we summarise the needs of target audiences and of the professional education.

2.1 Needs Related to the Target Groups

The continuous professional development is a hallmark of the knowledge society. All specialists in the field of electronics need regular re-training but nanoelectronics is not just designing nanoscale semiconductor devices but the physical principles are different as well the technology. So, there are real needs of courses in nanoelectronics design and technology.
2.2 Needs Related to the Vocational Education and Training

This project is designed to support the implementation of the "New Skills for New Jobs" strategy: "Nanoelectronics is a field that is still developing posing future skill needs… The main driver of the sector is the rapid technological change. However, the VET systems do not adjust as quickly. Thus, the rapid technological progress in production is confronted with the slow absorption by the VET systems. Consequently, a modernisation of the VET system with modifications in respect to more flexible and modular training offers is essential."

So, we need a new partnership between education and work to address the need of synergy between the education and industry, to foster the development of competencies, technological and entrepreneurial skills for the new jobs in nanotechnologies. The information and communication technologies have opened up a whole new potential to address the need of widespread access to VET, on-the-job and just-in-time.

3. Target Groups

The short-time target groups concerned are the trainees:

- professionals from SME in electronics and microsystems, who permanently wish to develop their competencies through recurrent education, working on projects and inspiring networks of peers;
- engineers from other sectors, e.g. from the chemical and biological sector, to be re-trained for the designing of electronic and optical components in particular in nano-optics and nano-electronics.
- educated but unemployed people (e.g. engineers, physicists, chemists) looking for additional qualification for employment.

This project targets the sector of electronics’ design and manufacturing and most precisely the nanoelectronics and nano-bioelectronics.

From institutional point of view the targets are the VET providers, human resources development departments at the enterprises in the sector of nanotechnology and higher education institutions providing practice-related vocational education in micro- and nanoelectronics. As no one training organisation can afford the extremely expensive infrastructures, equipment and maintenance of clean rooms for nanotechnology, collaboration and sharing of facilities and trainers’ expertise is of high institutional interest for all stakeholders.

The long term target groups are the same as the short term targets and from more VET providers and enterprises will be involved and other European countries as well.

Other users of project results will be:

- VET providers, trainers in HRD departments and university teachers in other sectors;
- managers in SME, universities and colleges;
- experts in public unemployment and social work institutions;
- producers of training materials.

They would find useful our experiences gained in the credits of learning units definition for ECVET development and the assessment methods of non-formal learning, and the lessons learnt in adjusting VET and practice-oriented HE programmes to make them more compatible with each other. They may transfer our experiences in their sectors and using our recommendations will be developed on how to enhance permeability and progression between VET and practice-oriented HE.

4. Objectives

The purpose of our project is to foster synergy and to exchange experience and resources of developers and users of vocational education and training for development of training courses in the emerging interdisciplinary sector of nanoelectronics. Its specific objectives are:

- Networking of project partners from SMEs, VET organisations, universities and social work institutions to share ideas, methodologies and experiences in order to improve the quality of the continuing VET to face the rapid technological change in the sector of nanotechnologies.

This objective addresses the needs of more responsive VET to the needs of the labour market.

- Analysis of labour market needs in nanoelectronics and nano-bioelectronics through problem and job analysis, and definition of necessary knowledge, skills and competences for engineers and technicians in the sector in terms of learning outcomes.

This objective addresses the need of definition of the new skills for the new jobs in nanoelectronics and the needs of improvement of transparency of qualifications.

- Development of Web-based training courses with modular structure to be used on-the-job as a performance support and just-in-time.

This objective addresses the needs of more flexible and modular training and the needs of new skills for ‘highperformance work practices’ in the new work organisation.

- Design the evaluation of learning outcomes of knowledge, skills and competences and perform a pilot test with quality assurance procedures
5. Need Analysis

To analyse the industry training needs a survey has been submitted at the European level [6] in the different countries of the project partners: France, Italy, Germany, Switzerland, Bulgaria and Israel.

We have first established a list of courses according to the miscellaneous competences available in the various universities which are involved in the project. The courses have been selected to cover as much topics as possible in relationship with nano-electronics. Fifteen different courses have been proposed:

- Bioelectronics
- Carbon nanotubes for field emitter applications
- Characterization and use of carbon nanotubes
- Defaults and non-invasive testing of nanodevices
- Design of nanoscale MOS integrated circuits (ICs)
- Impact of nano-metric effects on ultra large scale integration (ULSI) system performances
- Magnetic microsystems applications
- Microsystems simulation & characterization
- Nano-materials
- Nano-positioning and electrical nano-probes for nanoelectronics
- Nanoscale sensing elements and device production
- Nano-structures for optical and magnetic applications
- Next generation lithography
- Organic thin film devices
- Scanning probe microscopy applications for nanoelectronics

In order to easily collect the feedback from all potential customers, a WEB based survey has been set up. In order to define the priorities, it was important to collect not only the feedback of each person answering the survey but also to have an idea of the number of persons involved. By the way, a manager may answer for all his related team.

Thanks to SITELESC which is partner of the project, the survey has been submitted to many representatives of the microelectronic companies including the largest in the area as (ST Microelectronics, NXP (Philips), E2V, ATME, Infineon (Siemens).

We have collected 85 answers. This is a reasonable score considering the short delay we had to do this analysis in order to start courses development as soon as possible and in the time frame of the project. If we consider that most of the answers have been provided by managers leading large teams, the analysis should cover the needs of about 14500 persons. The chart (See Figure 1) shows the repartition of the responsibility level of the persons who answered the survey.

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After a detailed analysis of the needs (See Figure 2), both in term of interest and in term of potential trainees, a selection has been made among the proposed topics.

6. Development of Courses

The following eight courses are being developed to respond to the training needs of the industry (http://www.nanoskills.eu/ref/course_proposal.html):
• Microsystems design and characterisation
• Nano structures for optical and magnetic applications
• Nanoscale sensing elements and device production
• Impact of nano-metric effects on ULSI system performances
• Design of Nanoscale MOS ICs
• Nano-materials scanning probe microscopy
• Applications for nano-electronics (some parts of this course are taken from ‘Nano-positioning and electrical nano-probes for nano-electronics’)
• Carbon nanotubes for field emitter (cold cathode) applications (Some parts of this course are taken from ‘Characterization and use of carbon nanotubes’).

The learning outcomes are being defined for each course with the corresponding credits after assessment, adopted by all partners. Each course is designed by the best laboratory/department in the field which dispose with the necessary infrastructure and facilities for practical work.

Web-based course management and delivery software, such LMSs [7, 8], are becoming common in many areas of education. In NanoSkills there are e-learning courses and there will be mlearning performance support modules. Credits for each learning outcome unit are determined and specific tests for measuring knowledge and skills are designed and tested for recognition of formal and non-formal learning.

At this stage of the project Web-based learning materials are under development and professional videos of some lectures and of the practical work in the clean rooms and laboratories. The videos are made by the experts from Tel Aviv University. Live WebCasts of an event, with an interactive talkback facility, can further enhance the quality of the experience. Such a portal was built by Tel Aviv University for European NOE Nano2Life (http://n2lvip.tau.ac.il) and maintained during the whole life cycle of the project. The site as it is at the moment content around 300 lectures on Nano bio topics.

Several successful initiatives/projects have been carried out, either creating singular remote lab solutions (e.g. VISIR [9, 10], NetLab [11], DIESEL [12] and PEARL [13]) or community based approaches for delivering remote access to a pool of sharable laboratories among partners within a community (e.g. iLab [14], Labshare [15], and Weblab Deusto [16]), or integrating remote laboratories within LMSs to take the advantages of the services provides by LMSs such as communication tools, administration, and assessments (e.g. the middleware architecture described in [17-20], and LiLa [21]), or indexing remote laboratories within a metadata repository in order to facilitate for researchers to allocation of information about remote labs dispersed among many universities (e.g. Lab2go [22] and iLab Central [23]).

One of the laboratories developed in NanoSkills, based on live recording, is the experimental fabrication of nanogaps. In this laboratory custom electronic boards are used as control of the fabrication of the nanogaps. These boards are connected to a silicon chip, where some gold wires are pre-deposited, in which the nanogaps are created by electromigration. All the fabrication process is controlled by software application. So, in the laboratory different parts are present: PCB boards, a silicon chip and a software control.

Figure 3. Screenshot of a WEB based Lab

All these parts are presented in a video where, as can be seen in Figure 3, slides and live demonstration of the devices are done together, allowing to the student to have a precise perception of which are the components involved in the hands-on work and in the meantime the practical procedures are clearly explained.

In another module developed in NanoSkills, within the course on Carbon NanoTubes (CNTs) and their use in nanoelectronics, a video related to the preparation of the CNTs was recorded. In that recording it is practically shown which are the steps in a laboratory to fabricate CNT electrodes.

The SMEs in the sector can not afford all facilities for fabrication and are used to rent clean rooms and equipment at foundries or research units at universities.

They need practical training for their employees who will work with the equipment. For their purposes some practical training modules are being designed by CIME NanoTech, France, Polytechnics of Torino and the laboratories of the enterprise AMGT.

7. Implementation

The last year of the project is devoted to the implementation of the joint delivery of the courses. The pilot test will be conducted with small groups of learners
form the SMEs and partner universities – minimum 15 trainees.

The pedagogical effectiveness will be measured with knowledge tests, practical projects performance, questionnaires and interviews. The question will be whether the learning based on courseware, ICT-based materials, and practical work if any, prove pedagogic effectiveness as indicated by performance, attitudes and perceptions of students? Do the learners reach their performance objectives (specifying what the learners must do after the course) and the learning objectives (specifying what the learners must learn during the course)? I.e. are the learning outcomes attained as defined in the qualification?

After changes/improvements of training materials, support, practical work if needed, the field trial with larger audiences will be done – minimum 60 trainees. They will be from SMEs, professionals with different from microelectronics background, students from the last year of their MSc degree in electrical engineering.

Before the training, the professionals from the SMEs in the field would be asked to pass the tests. This will have double effect: those who have passed successfully the test do not need training and will obtain certificates for the corresponding credits. For those who could not pass the tests, they will be considered as pre-tests and at the end their results from the pre- and post-tests could be compared.

In the field trial students from MSc degrees in nanoelectronics from the partner universities will be involved and comparison, adjusting of credits in higher education and VET will be made. These activities will be done in collaboration with the project NanoEl funded by the European commission, programme Erasmus. Tests of the ECVET application to VET qualifications and recommendations how to enhance permeability and progression between VET and practice-oriented HE will be done. So the universities are being sharing their infrastructure, technological and human resources, they will recognise the common certified modules but each university will keep his autonomy regarding the national diploma delivery.

After the pilot tests, the courses will be integrated in the regular training activities of the partner institutions and should be up-dated every 6 months at the rate of the nanotechnology change. The partners-developers will care about this update and continue their collaboration after the project end. In a case of commercialisation, the product will be sold with a condition of upgrade. To facilitate the use of the course materials, they will be translated in all partners’ languages depending on the user needs.

By the end of the project an agreement will be signed by the partners for the intellectual property rights with a view of possible commercialisation.

The project partnership will be enlarged with involvement of VET and HE providers from other sectors and will establish co-operation with other Leonardo and Erasmus projects to transfer the project results, to continue the collaborative ECVET creation and to facilitate the compatibility, comparability and complementarity of ECTC and ECVET and to improve the validation of non-formal adult learning outcomes, within the learning community in Europe.

8. Conclusion

In this manuscript we presented a work in progress within the European community project “Training new skills for the new jobs in nanotechnologies”. At this stage in the project lifecycle we have defined the learning outcomes the courses are designed and the e-learning materials are developed.

The innovations that the project offers are:

- The content of the courses: nanotechnology is an emerging multidisciplinary science and new jobs in the sector require new professional skills.
- New approach - collaboration of different stakeholders:
  - training providers and users (SMEs and professional associations) to develop vocational skills considering the labour market needs and
  - VET and HE providers to contribute to the improvement of transparency and recognition of competences and qualifications and to make them more compatible with each other and to facilitate and promote progression from VET to HE.
- Recognition of qualifications and competences in the sector, including those acquired through nonformal and informal learning through assessment procedures of learning outcomes;
- Enriching the collaboration of LLP countries with Switzerland and a third country – Israel.

The main expected impact on the target users is: the opportunity to have certified training of new skills for the new jobs in nanotechnologies; recognition of learning outcomes achieved in formal and, where appropriate, nonformal and informal contexts; on the VET system: contribution to the ECVET creation, promotion the progression from VET to HE.

Acknowledgement

This project (“Training New Skills for the New Jobs in Nanotechnology” no. 510591-2010-LLP-FR-LEONARD-LMP) has been funded with support from the European Commission, Leonardo da Vinci programme. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.
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