Master Degree Modules in Nanotechnologies for Electronics

Final Report Public Part
## Project information

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Executive Summary

The NanoEl project focuses on sharing the technological and human resources available at each partner university to develop teaching modules/courses in the highly interdisciplinary area of nanotechnology; certified, based on ECTS, to be used in the partners’ MSc programmes in nanotechnologies.

Its main target audiences are:
- the students in micro- and nanoelectronics. They need high-quality educational materials, and continually brought up-to-date courses, because of the essence of nanotechnologies - the most rapidly advancing sector now a day. They need education related to their further work and for the complexity of the knowledge and skills, necessary to perform successfully the tasks in this multidisciplinary science determines the needs of “practical training”.
- their teachers. They need infrastructure, modern equipment and facilities for teaching nanotechnologies, they need techniques for course delivery allowing easy changes and upgrade because of the fast developing science of the subject matter, i.e. ICT-based materials.
- university management. It is convinced of the necessity of European dimensions in higher education, particularly with regards to curricular development, interinstitutional cooperation, virtual mobility of students and academic staff, and integrated programmes of study, training and research.

From institutional point of view the targets are the higher education institutions providing accredited MSc. degrees in micro- and nanoelectronics. As no one university can afford the extremely expensive infrastructures, equipment and maintenance of clean rooms for nanotechnology, collaboration and sharing of facilities and teachers’ expertise is of high institutional interest for the universities.

The project objectives are:
- To analyse the educational needs in nanoelectronics and nano-bioelectronics through problem and job analysis, and to define the necessary knowledge, skills and competencies of engineers in the sector in terms of learning outcomes.
- To design syllabi and course content for regular and continuing education for master degrees in nanoelectronics and nano-bioelectronics based on ECTS and recognised in all partner countries.
- To develop lessons for higher order skills and learning materials for e-learning mode of delivery.
- To develop lessons for practical work in the high-tec laboratories of partner institutions as a part of the partners’ MSc degree programmes.
- To start the implementation of the joint modules/courses delivery.

There are few individual research teams, laboratories or companies that can claim to be able to respond to the technological challenges. To meet these needs in this project three European universities shared infrastructure, technological and human resources and they recognised the common, based on ECTS, certified modules, used in the partners’ MSc programmes in nanotechnologies.

Each course was designed by the best laboratory/department in the field which disposed with the necessary infrastructure and facilities for practical work. They developed e-learning courses and recorded the practical work in clean rooms in
nano/biotechnologies. After a successfully passed test, the students performed a short mobility of one week for the practice in the partners’ laboratories.

The learning outcomes were defined for each course with the corresponding credits after assessment, adopted by all partners. These credits were transferred to the MSc programme in nanoelectronics at the partner university where the student was enrolled. So, the universities shared their infrastructure, technological and human resources, and recognised the common certified modules but each university kept his autonomy regarding the national diploma delivery.

The added value for the students is in the highest quality of the specialised courses developed by the best departments in the field, but they mostly appreciated the opportunity to train practical skills and competences in the laboratories with advanced equipment and facilities.
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1. Project Objectives

- To analyse the educational needs in nanoelectronics and nano-bioelectronics through problem and job analysis, and to define the necessary knowledge, skills and competencies of engineers in the sector in terms of learning outcomes. This objective addresses the need of definition of new skills for new jobs in nanoelectronics and the needs of improvement of transparency of qualifications.

- To design syllabi and course content for regular and continuing education for master degrees in nanoelectronics and nano-bioelectronics based on ECTS and recognised in all partner countries. This objective targets the interdisciplinary sector of nanotechnologies and the needs of closer cooperation in the university sector using the infrastructure, technology and expertise of partners’ universities.

- To develop lessons for higher order skills and learning materials for e-learning mode of delivery. This objective addresses the needs of skills and competences for ‘high-performance work practices’ in the new work organisation.

- To develop lessons for practical work in the high-tec laboratories of partner institutions as a part of the partners’ MSc degree programmes. This objective addresses the need of sharing an expensive infrastructure, clean rooms maintenance, technology and even experts in all fields for effective education in the multidisciplinary science of nanotechnology.

- To start the implementation of the joint modules/courses delivery. This objective addresses the necessity of striking a balance between what is offered in the educational system and what is needed in the sector.

Teachers and managers were involved in the need analysis, in the learning outcomes definition and in the whole process of syllabi, content and learning materials development and delivery process. They were involved in the definition of credits of courses with regard to the ECTS and in the elaboration of a table of reference of grades in each country. Students from the MSc degree, especially in their first year and from the bachelor degrees in electronics were involved in the need analysis and in some tests of e-learning prototypes. The implementation of the joint modules/courses delivery was done during the last, third year of project lifetime with the pilot test and as a part of the regular curricula (the elective specialised courses) of the MSc degrees at each partner university. A total of 585 students followed the NanoEl courses, and 38 of them participated in the short term mobility in partners’ countries for the practical work. Students were very positive to the collaborative course delivery but they appreciated mostly the opportunities for short term mobility for practical work at the partner universities. The added value for the students apart of the highest quality of the specialised courses developed by the best departments in the field, was in the opportunity to train practical skills and competences in the partners’ laboratories with advanced equipment and facilities.
2. Project Approach

Because of the differences of national lows in each country, the accreditation of joint or multiple MSc degrees was not possible. So, the universities shared their infrastructure, technological and human resources, and they recognise the courses/credits developed and delivered in the NanoEl learning environment but each university kept its autonomy regarding the national diploma delivery. To facilitate the implementation of the results, the new courses were added to the list of electives to avoid complicated procedures of a whole curriculum change in each university/polytechnics.

In the e-learning materials development, a prototyping approach was used. Expert review and design walkthrough in all stages of prototypes production provided information and corresponding feedback to developers for ensuring the quality of content and usability aspects of prototypes, and they helped to validate the efficiency of chosen methods and media as early as possible. Learners were involved in the evaluation process at all stages. A written feedback to gather data on learners’ and teachers attitudes and opinions was required after the pilot test.

Before the implementation of courses, training of tutors was performed during the meetings in Grenoble in March 2012 and in Sapareva Banya in October 2012. Later the teachers from each partner university trained all tutors involved in the teaching of concrete courses in their institutions.

Each course was designed by the best laboratory/department in the field with the necessary infrastructure and facilities for practical work. After successfully passing the test on the e-learning course, the students performed the practice in the partners’ laboratories, followed by practical assessment. The mobility was for one week of practice in CIME Nanotech in France and in POLITO. The practical work for the course developed by TUS was implemented with remote access to the professional software available in its laboratories. The course on microsystems was delivered collaboratively with INPG who developed the e-learning course and with a Bulgarian SME AMG technology in which clean rooms the practical work was done.

Each course was designed for specific learning outcomes, with credits for each course unit to be given after assessment, and adopted by all partner institutions. These credits were transferred to the MSc programme at the partner university where the student was enrolled.

Quality assurance (QA) was an integral part of the internal management of all partner institutions following the standards in the European Higher Education Area and the new courses are objects of these QA procedures. Quality management of the WPs: project evaluation by two external evaluators: one expert in nanotechnologies and one expert in educational sciences; evaluation of intermediate and final reports by LLP Executive Agency.

During the third year of the project lifetime the courses developed were integrated in the regular MSc degree programmes of the partner institutions and with this purpose they were developed.

The added value for the students is in the highest quality of the specialised courses developed by the best departments in the field, but they mostly appreciated the
opportunity to train practical skills and competences in the laboratories with advanced equipment and facilities.
3. Project Outcomes & Results

Quality assurance plan

Need analysis report with learning outcomes for each course

Syllabi of courses in:

- Microsystem design and characterization,
- Bioelectronics,
- MOS fabrication and characterization,
- Introduction to nanosensors,
- CAD for nanoscale transistors,
- ULSI devices and novel simulation techniques.

e-learning courses and video records of some lectures and of the practical work in the clean rooms and laboratories (http://moodle6.tau.ac.il/nanoel/)

The following practical modules for practical work in the laboratories and or clean rooms of partner institutions were developed as a part of each partner’s MSc degree programmes:

- Microsystem design and characterization,
- Bioelectronics,
- MOS fabrication and characterization,
- Introduction to nanosensors,
- ULSI devices and novel simulation techniques,
- Remote access to CADENCE for ICs design,
- Microsystems fabrication and testing.

Student guides for each practice and videos on the clean room practice were developed.

The implementation of the joint modules/courses delivery started during the third year of the project. The courses developed entered in the regular curricula of the MSc degrees at each partner university from September 2012 as elective courses with the corresponding credits based on the ECTS. So, not all students studied all courses but minimum 40 students per partner institution were involved in the pilot test. First the e-learning courses (each one for 3 months) were delivered with distant tutoring (e-mail, Skype). After successful test on the e-learning module of each module the learners could make the practical work in the clean rooms available in the home university and 6 or 7 students per country – in the partner universities. The student mobility was for one week practical work in partners' laboratories.

The practical modules assessment was based on the results of the tasks to be performed in the laboratory. After successful assessment the student obtained a certificate with the corresponding credits.
Students who participated in the exchange for the practical training and teachers provided written report on their attitudes, satisfaction, in order reveal problems if any and to improve the courses and the collaborative MSc degree courses delivery.

The project results were presented on 4 conferences, a paper was published in one journal, publications - in two online newspapers, presentations of results to the consortiums of other LLP projects were done, a leaflet in all partner languages was designed, Web pages in all partner languages on their own servers were developed, leaflets in all partners’ languages produced, a demonstration CD were developed and demonstration video published in YouTube.
4. Partnerships

There are few individual research teams, laboratories or companies that can reasonably claim to be able to respond to the technological challenges. Even the big companies in the sector work with a common use of R&D resources. No one university can afford the necessary infrastructure, clean rooms, technology and experts in all fields of the multidisciplinary science of nanotechnology.

So, to respond to the needs identified for training new skills for new jobs, in this project three European universities shared their infrastructure, technological and human resources and recognised the common certified, based on ECTS, modules, to be used in the partners’ MSc programmes in nanoelectronics.

The European added value is in the closer cooperation in the university sector for sharing technical and scientific high-tech facilities to deliver certified courses, based on ECTS, and used in the partners’ MSc programmes in nanotechnologies for electronics and promoting transparency of qualifications and recognition methods.

The added value of the collaboration of partners from different European countries is:

- in the content of the courses: nanoelectronics is strategic multidisciplinary science and it is in the bases of all economical sectors. The subject matter of the courses is the main contribution to the national, European and could have added value to the world education in high-technologies (the new TEMPUS project in nanotechnologies with Israel was designed and it is already selected for financing);
- in the new forms of co-operation between partner organisations - sharing the technological facilities and infrastructure in addition to the expertise;
- in the larger impact of results and experiences;
- in the larger opportunities for valorisation of project results.

The innovative solutions provided by this project are:

- Sharing of resources, which a single university can not afford, for improving the education in high technologies for the new jobs in nano-bionanotechnology in the LLP countries,
- Enriching the collaboration in sharing resources with – Israel and Switzerland (prof. Silvia Schintke from HEIG-VD, Switzerland participated in the project without financing of SNSF).
- Virtual mobility: In this project the mobility is mostly virtual thanks’ to the e-learning courses and only for the practical modules a short student mobility of one week was done. In traditional scheme of common degree delivery and even within Erasmus mobility programme the students need to stay 4 semesters abroad and to follow the courses delivered in their country during additional semesters. The students appreciated mostly the short term mobility and the practice performed in the partners’ laboratories.

Five papers published
5. Plans for the Future

With the experiences gained and lessons learned during the pilot test, the consortium decided to continue with this scheme of collaborative use of courses in the MSc degrees of each university and when national legislations will allow it, to apply for accreditation of the MSc programme with a joint or multiple degree. The later will depend on the eventual changes in the national laws of each country which today differ a lot and at this stage the accreditation of joint degree is non-realistic. During the final project meeting an exploitation agreement was signed for the further use of courses and continuation of the collaboration at the MSc degree level.

The project results were reported in one journal and on 4 national and international conferences in education and in nanotechnology in order to obtain duly feedback and to improve the processes and products of the project, and to extend the project network with new potential users.

By the end of the project a Demo CD was produced and a leaflet in the languages of participating countries and in English. In September 2013 an open workshop for dissemination of project results was organised at POLITO.

The experiences with collaborative MSc courses and student tutoring will be transferred to a Doctoral degree level. The possibilities for collaboration at PhD level were examined during the project lifetime and decisions for collaborative tutoring of PhD students were taken. Co-tutoring practices of PhD students between INPG and TUS existing since 2000 will continue and new contract for Erasmus mobility including exchange of PhD students was signed between POLITO and TUS and a new one for the 2014-2020 was signed in November 2013.
6. Contribution to EU policies

The project addresses the needs of training new skills for new jobs and the needs of sharing facilities and expertise in high technologies. The problems addressed by the project and the solutions proposed are in conformity with the conclusions and suggestions of the studies financed by the EC:


The project targeted higher education students. It was aimed at improving the quality of lifelong learning through sharing facilities and expertise in nanoelectronics courses development where no one university can afford sufficient infrastructure and equipment.

For the knowledge and cognitive skills training the learning materials are ICT-based and the content is based on the last research results and practices in the most rapidly developing science. The e-learning allows virtual mobility of students and easily update of the contents which should be innovated every year.

The project addressed the priorities of ERASMUS curriculum development with its aim to share the technological and human resources available at each partner university to develop teaching modules/courses in the highly interdisciplinary area of nanotechnology; certified, based on ECTS, to be used in the partners’ MSc programmes in nanotechnologies. The courses clearly define and promote learning outcomes and competences in nanoelectronics in line with national and European qualifications frameworks, aiming at future skill needs in the sector.

All project activities and results support the achievement of the European Area of Higher Education.

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