Physics education in Europe – as revealed by steps two project

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The STEPS TWO (Stakeholders Tune European Physics Studies TWO) project brought together Physics Departments from more than 70 universities from Europe to strengthen European links and dialogue within the Physics discipline and to stimulate cooperation in the European Higher Education Area. The project's objectives were focused on three major themes: Curriculum innovation and new trends in educational offer, Modern teaching in physics and Physics teacher education, aiming at helping university Physics Departments to have a greater European vision in their strategic institutional development, following the structural changes of the Bologna process and in their response to the Lisbon goals (e.g. increasing the number of Physics graduates).
In terms of outcomes the project has concentrated on (a) producing 'benchmarks' for physics degrees and for teacher training, (b) creating a large database on 'New methods in physics teaching' including an evaluation of their effectiveness, and (c) conducting and reporting on a large survey of 'Physics teacher education' throughout Europe (partly translated into several EU languages). In all these areas, recommendations have been made and concrete strategies offered.
The outcomes of the project are important for all higher education institutions providing Physics and related Physics course degrees, academics and students in Europe and not only, as well as for organizations which have a role in pre-university physics learning or in quality assurance of education in physics.

Keywords: Physics, Education, Europe.

The Higher Education sector in Mathematics, Science and Technology is expected to play a major role in the process of innovation and development in the knowledge based society (EC Communication 2003 "The role of the universities in the Europe of knowledge"(http://europa.eu/legislation_summaries/education_training_youth/lifelong_learning/c11067_en.htm). An understanding of the key principles and ideas of physics is important for solving important global problems such as electrical energy generation, renewable energy, new forms of transport and global warming. The scientific and technological innovation, which is the main engine for growth and for enhancing the economic competitiveness, is highly dependent on good teaching of physics in schools and universities [1], [4].

The STEPS TWO (Stakeholders Tune European Physics Studies TWO) project, funded for three years by the EU Lifelong Learning Program (LLP) and with some support from the European Physical Society (EPS), followed the earlier STEPS project. The STEPS TWO consortium was based on former EUPEN (European Physics Education Network) partners. The EUPEN Consortium was started in 1995, by Hendrik Ferdinande (University of Ghent), initially in response to the increasing mobility of physics students across Europe in the frame of the EMSPS (European Mobility Scheme for Physics Students) ─ established in 1992 with the support of EPS [1]. The academics involved in student exchanges realized that there was a need to investigate and compare the physics degree programs of different European countries, as well as the different teaching and learning methods. The number of physics departments in EUPEN has always been large and stakeholder organizations (professional, student, research) joined the academic network in many TN (Thematic Networks) projects: EUPEN, STEPS, STEPS TWO.

The STEPS TWO Consortium was built by 70 partner institutions from 27 LLP─eligible countries and 5 associated partner universities from other non EU countries (Croatia, Russia, Macedonia, Yugoslavia, Ukraine). All partners award university degrees (BS, MS and/or PhD) either in physics and/or physics ─ related subjects (astronomy, biophysics, oceanography etc.) and/or engineering (or applied) physics. Two professional associations were involved, representing the most important

stakeholders for the project: EPS having national branches in more than 40 countries and a strong Education division and European Physics Students Initiative (EPSI) ─ a student association of Physics students from a large number of European universities. All persons, institutions and organizations directly involved and responsible for running the project activities had long standing experience in Physics higher education and well-established links with secondary education. About 88% of science teachers' education in Europe is done by universities. Most of the partners have played leading roles in either European TN projects or TUNING projects proving excellence in networking activities and European cooperation. The STEPS TWO project has been led jointly by University of Bucharest (Professor Laura Ţugulea ─ coordinator) and University of Antwerp (Professor Jan Naudts ─ contractor).

STEPS TWO aimed at supporting physics departments in partner universities in their strategic institutional development following the structural changes by the Bologna process, with greater European vision [1,2]. From the perspective of European ─ wide mobility and employability, it is no longer useful to limit frameworks at subject area and sectorial level to regions and nations. In the process of reconsidering their traditional curriculum, universities need to give a higher priority to mobility, to interdisciplinary and transdisciplinary approaches.

The project's objectives were focused on three major themes: 1) Curriculum innovation and new trends in educational offer, 2) Modern teaching in physics, and 3) Physics teacher education, aiming at developing recommendations and offering solutions for concrete strategies [2, 3, 4].

All the three themes relied on stringent demands of education reforms in Europe: to identify the status after Bologna process, to improve the teaching of Physics by new methods and methodologies, to bridge the gap between high school and university. Physics and interdisciplinary approach, physics for non-traditional students, teacher education for training physics teachers at all level (primary to university) for European schools not only local ones were settled as directions of investigation. The modern concept of "student centered learning" and methodologies using Information and Communication Technologies (ICT) and Multimedia (MM) are innovative fields in education and for Physics discipline are very important.

The activities, including exploitation and dissemination of results, were executed by three working groups and all activities have been evaluated and validated by recognized experts (Professor Ove Poulsen, Aarhus University, Denmark and Professor L.J.F. Hermans, Leiden University, The Netherlands) [5]. The results of the three working groups are extensive and were presented during the forums organized in Vilnius, LT (2009), Paris, FR (2010), Limassol, CY (2011) and disseminated by the STEPS TWO web-site [2] and dissemination web-site [3], and the comprehensive booklet [4].

The principal project deliverables are listed below:

- Eurobenchmarks for Physics Bachelor Degrees in the Post-Bologna era, confined to curricular aspects and particularly useful for all of Europe's Physics Departments in degree program design, development, assessment, and promotion of student mobility (WG1 OUTCOMES/Benchmarking the Bachelor in Physics [3]).
- First inventory of unconventional Bachelor programmes in Physics or with Physics as a major component (FORUMS/Forum in Vilnius [3]), [4].
- A database with examples of modern teaching methods and applications of student ─ centered learning approaches (WG2 OUTCOMES [3]).
- The results of an investigation of multimedia resources for physics teaching in universities and schools including an evaluation of their effectiveness and actual usage (FORUMS/Forum in Paris [3]), [4, 6].
- The results of an investigation of the existing structures and methods for the teaching of physics and the training of physics teachers at all levels, with special emphasis on secondary school level, particularly an investigation of the reasons for the shortage of physics teachers in many parts of Europe and of steps which can be taken to address this problem (WG3 OUTCOMES [3]), [4, 5, 7].
- The survey of 'Physics teacher education' throughout Europe was partly translated into several EU languages [3]. The Romanian translation was done by Nicoleta Stefu and Adrian Neculae (West University of Timisoara, Romania) and is posted on the web-site (WG3 OUTCOMES/ROMANIAN TRANSLATION [3]).
- Eurobenchmarks for Physics Teacher Education Degrees, concentrating on teachers in upper secondary school (WG1 OUTCOMES/ Benchmarking the Physics Teacher Education [3]).

The results regarding the new trends in educational offer show that in most countries, a large proportion of Bachelor graduates continue with a Master program. The overwhelming majority of beginning Bachelor students intends to pursue a Master program as well (FORUMS/Forum in Vilnius [3, 4]). International mobility has a long and

successful tradition in physics and can make a valuable contribution to student's scientific and personal development. Research collaboration could also be used to further student exchange, especially in the Master and doctoral cycles. Students who went abroad are in general satisfied with their experience (FORUMS/Forum in Vilnius [3, 4]), although the support provided by some home institution could be significantly improved.

The Benchmark documents specify necessary standards for degree programs and in general cover both competences (learning outcomes) and a core curriculum (WG1 OUTCOMES [3, 4]). Since competences for Physics Bachelor Degrees have been formulated by TUNING project [8], the Bachelor Eurobenchmarks, developed by the WG1 task force, confined themselves to curricular aspects [4].

Non-conventional teaching in Physics includes: problem based learning, project based learning and other student ─ centered learning, such as peer instruction, just-in-time teaching, brainstorming and library research. The results regarding the usage of new methods and multimedia in physics teaching are characterized by a wide variety among universities and schools in Europe. This variety refers to the type of teaching of multimedia, the way it is used, the level of education, the content of the subject and the organisation of the education. New methods of teaching and multimedia are and will be a valuable tool in teaching and learning processes in physics, in all levels of education from primary level, secondary level to university level and especially for the education of physics teachers.

In almost every country there are new developments in physics teacher training or new developments are expected in order to alleviate the serious shortage of physics teachers.

In several countries physics education in schools is confronted with problems such as:

• insufficient investments in tools and labs;

• insufficient equipment for experiments in class with the result that lessons become highly theoretical;

• pupils' low interest in physics;

• overloading of teachers in a classroom makes their job difficult;

• lack of the training in Physics and Pedagogical Content Knowledge of teachers for teaching new reformed curricula.

Recommendations have been made and concrete strategies offered [3, 4] for all higher education institutions providing physics and physics ─ related course degrees, as well as for organizations which have a role in pre-university physics learning or in quality assurance of education in physics. A selection of such recommendations, issued by STEPS TWO following the three major themes of the project, is presented below.

Curriculum innovation and new trends in degrees offer.

- Refer to Eurobenchmarks when designing Bachelor programs by Physics departments and in promoting vertical mobility.
- The promotion of student mobility should be an important aim in curriculum design and implementation (e.g. introduction of "mobility windows").
- Enlarge the offer by additional, un-conventional, in general interdisciplinary Bachelor programs in Physics or with Physics as a major constituent.
- Encourage students to follow "nontraditional" ways and to shape some of their studies individually.
- Consider flexible cooperation with business and research organizations, including visits of staff and mobility of students.

New teaching methods in physics

- New methods of teaching and use of multimedia should be a valuable tool in teaching and learning processes in physics, not only in traditional education but especially in a framework of "in-service training", "long distance learning" and "life-long learning".
- Their use should focus not only on the technical and practical aspects of the methods, but in particular also on didactic aspects, with the aim of better understanding of the impact of these materials on the development of physics related skills and transferable skills.

Physics in the School Curriculum and the Shortage of Physics Teachers.

- There should be financial and other incentives for physics graduates to train to become physics teachers.
- Encourage and help physics students to make a career in physics teaching, pointing out the importance to society and intellectual satisfaction of such a career.
- University physics departments should do what they can to help local secondary schools provide a good education in physics by interacting with them and providing activities in laboratory work and 'master classes' in advanced physics as well as visits to schools by physics students to inspire pupils and assist teachers.

At the end of the STEPS TWO project, Professor Gareth Jones (Imperial College London) stated that

"There was a feeling at the end that we had been working on problems which have great importance for the economic well-being of Europe and particularly for creating the next generation of innovators and for the development of new technology. Considerable progress has been made but much remains to be done" [7].

Acknowledgements

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