

The educational challenge:

A new deal between science teaching and science and society on *physics in schools*

Forum Physics and Society (FPS), an outreach body of the European Physical Society (EPS), aims at establishing a more active EPS role in the relation of physics to society, taking seriously the challenge of maintaining a strong and critical dialogue between physicists and decision makers from policy and economics. FPS catalyzes such development through workshops and meetings, gathering decision makers and physicists to put the spotlight on topics of interest to both society and to the physics community.

The third Forum Physics and Society event took place in Ratnieki, Latvia 15-16. April 2009. The meeting brought together 44 science teachers and researchers from schools, universities and industry, scientists involved in teacher training as well as decision makers in science policy from 16 European countries. They discussed the role and the aims of preuniversity science and physics education in Europe. Invited keynote speakers supported the discussions by in depth analysis of selected issues.

The discussions were focused around, firstly the worrying situation concerning teacher training both at elementary school level as well as on the upper secondary school level, secondly the observation that most countries share the same educational challenge and finally the more serious fact, that no country yet has a clear policy to solve these problems.

The challenge involves society as a whole. Society depends on scientifically literate citizens. Science, and physics particularly, are central to many professions outside the sciences and physics is a driver for modern science both conceptually as well as in the advancement of novel technologies.

The forum overall agreed on a series of *recommendations* which are essential

- for science teaching to be successful in raising science literacy and
- in maintaining science, in particular physics, as a driver for development of many professions and
- for physics to continue to be a driver within the sciences as well as an innovation catalyst in society at large.

Overall recommendations

FPS *recommends* that national agencies and European institutions

- maintain and improve the quality of physics teaching
- agree on an increasingly higher standards for the training of *physics teachers*
- strengthen and coordinate applied educational research at all levels across Europe
- ensure rapid deployment of the results and best practices of educational research and experimentation
- establish regular contacts between universities and the physics teaching community
- ensure interaction and co-operation between all three educational levels: *Elementary – Secondary – University*
- ensure appropriate budget for the support of such program

National Physical Societies are asked to start a discussion process in their country with decision makers in science policy as well as with teachers, to ensure dissemination of the recommendations.

Specific recommendations

The overall recommendations are supported by more specific recommendations relating to the diverse roles played by physics in the educational system. Physics teaching must be geared to students' ages, abilities and degree of specialization (where initially physics may be taught as a topic in a family of learning comprising science literacy and, later for those more interested, as a discipline in its own right. These questions were dealt with on two broad levels, but effectively in three categories:

- physics for all - as part of culture (science literacy)
- further physics studies
 - for the interested students - with a professional dimension (for careers not necessarily connected with science)
 - for the selected - with a science outlook

The FPS workshop agreed on an implementation of specific measures for each level, after considering a wide range of problems:

- teacher specializations and teacher competencies
- specific curricula development
- the role of experimentation and practical work

To facilitate efforts of teachers EPS, together with National Physical Societies, should more actively support physics education by

- creating a data base of national science education initiatives to share materials and best practice for physics teaching
- initiating common activities on an European level for interested students,
- supporting visits and exchange of teachers with a minimum amount of bureaucracy,
- creating an European science qualification certificate
- supporting European initiatives to present modern physics in the media (especially in the television) to gain public attention

In addition, some preconditions regarding society's attitude and responsibility towards teachers are necessary:

- freedom to shape their curriculum
- more efficient teaching evaluation process
- value teacher's professionalism and their contributions to society
- better working conditions (salary, smaller classes, career development, mobility, ...)
- wider professional networking
- trust

Based on these preambles the three levels of physics teaching are addressed separately.

Physics teaching for all (science literacy)

- 1.1. The physics curriculum in schools should:
 - be reviewed critically to ensure as far as possible that its content is of potential value to students, both female and male, in order to answer their own questions and help them deal in a more informed way with situations in which they may find themselves in everyday life, both now and in the future
 - provide opportunities for students to carry out experiments and practical investigations to collect data and to test and develop their ideas and understanding
 - provide opportunities for students to discuss with others their ideas and explanations about natural events and phenomena, to evaluate the ideas and arguments of others, and to learn how to develop arguments based on observation
 - convey to students a sense that physics is a continuing endeavor, that many questions remain unanswered, and that physicists continue to work on major questions about the natural world, what it is made of, and how it works
- 1.2. Today's physics should be introduced early in a more systematic way at school. A good balance has to be found between modern physics, which can be taught predominantly in a qualitative way, and classical physics.
- 1.3. Teacher training and in-service courses are essential components in a successful introduction of modern physics at school.

- 1.4 Physics at school has to include relevant practical work on all levels in order to train skills in asking and answering questions and in order to build a bridge to every-day experience. The teaching process should start from simple experiments. Formal thinking and modeling should be introduced afterwards as a complementary tool to experiments and should arrive at a later stage as a necessary step in the mathematical description of physical phenomena. The institutional context for teaching physics has to be designed accordingly.
- 1.5 Adequate competencies in physics as well as in physics teaching (theory and practice) are required for all professionals teaching the subject.

2. Physics for the interested with a professional outlook

Physics education for interested students should take into account the relevance of physics for the developments of natural sciences, technology, medicine and many other fields.

Interested physics students between age 11 and 18

- recognize that physics is necessary for a future career
- are curious, ask questions, have own interests (not only in physics)
- start own activities (reading books, doing own experiments, ...)
- accept that mathematics is necessary for physics
- usually enjoy taking part in competitions

Teachers might keep and foster the interest in physics by

- helping students to find their abilities in thinking scientifically
- improving students' participation in classroom teaching by doing experiments on their own
- asking open questions to let students find their own, creative solutions
- fostering the imagination of students and helping them to ask their own questions
- starting teaching from common sense and well-known facts and not from the general theory
- showing students the beauty of physics
- inviting scientists to give talks in schools
- participating in activities like Science Week and other public presentations

To fulfill these objectives, Forum Physics and Society recommends, that:

- 2.1 in-service teachers training is necessary along with highly qualified teacher training institutions at university level
- 2.2 teaching interested students must include hands-on experiments
- 2.3 cooperation with external groups in universities, industrial laboratories and science museums should be encouraged
- 2.4 EPS should increase efforts to support teacher training as well as physics education

3. Physics teaching for the select

There is a large variety of educational systems in Europe, but in most of them insufficient attention is paid to under- and overachievers. Although there is currently much focus on developing and funding education and research at university level, primary and secondary level education must be strengthened. The word 'select' means here that these students are heading towards higher education and a professional careers in science because of their curiosity and critical intelligence, their personal interest, their own achievement, and their success in tests and competitions.

Some recommendations are:

- 3.1 Avoid using age limit criteria and formal national selection process
- 3.2 Use existing local infrastructure rather than dedicated schools for the gifted
- 3.3 Foster interaction and collaboration between high schools and university by organizing master classes, topical workshops, as well as visits to academic and industrial R&D laboratories
- 3.4 Recognize the important role of teachers
Indeed teachers play a leading role in selecting and advising the best students.

For this purpose they need to

- have or develop talent in scouting, tutoring, mentoring, and quality management
 - foster curiosity towards modern science and its applications
 - stimulate scientific literacy, in particular among the more gifted students (selects)
 - allow differentiation concerning topics and levels
 - participate in life-long learning programmes fostered by universities and national laboratories
 - interact with science museums, special public or private foundations and possibly also with industry
- 3.5 Improve society's attitude and responsibility towards teachers;
It is important at this level to
 - allow more freedom to teachers in shaping their own curriculum
 - recognize and value their professionalism and contributions to our society
 - improve working conditions (salary, smaller classes, career, development, mobility, ...)
 - contribute to the teaching evaluation process
 - promote professional networking
 - establish trust in their work
 - 3.6 Selection processes among students (talent spotting) should be supported by
 - science ambassadors (selected by National Learned Societies)
 - alumni (former participants in national and international competitions, like Physics Olympiads, IYPT)
 - outreach activities such as science festivals, competitions or fairs (e.g. Science on Stage, etc.)
 - providing appropriate science content for web and media
 - shaping curricula and examination processes