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Index

What is Physics On Stage?

Physics is everywhere, but how much do people in Europe really know about physics?

Physics On Stage is a unique European-wide programme for physics teachers and those in fields related to physics to assess the current situation in physics education and raise the public awareness of physics and related sciences.

The project was initiated by the three major European research organisations: the European Organization for Nuclear Research (CERN), the European Space Agency (ESA) and the European Southern Observatory (ESO), with support from the European Union. Other partners in the project are the European Physical Society (EPS) and the European Association for Astronomy Education (EAAE).

The objectives of Physics On Stage are:

- to draw attention to the low level of scientific (and particularly physics) literacy among European citizens
- to propose innovative and practical solutions to this problem
- to establish a network of experts on physics teaching and popularisation from all over Europe
- to produce and distribute materials that highlight the opinions and recommendations of these experts.

National Steering Committees were set up in 22 European countries[1], with the support of the EPS and EAAE networks. During the course of the year 2000, a wide variety of national activities took place to identify outstanding projects and individuals in the field of physics teaching and popularisation.

The highlight of the Physics On Stage project was a unique, five-day festival held at CERN in Geneva between 6 – 10 November 2000. More than 500 people from the participating countries met to exchange ideas and discuss how to improve the current situation and motivate the youth of today to become the scientists and engineers of the future. Approximately 300 of these were secondary school teachers, with the potential to amplify the ideas presented at Physics On Stage to over 40000 students.

The festival revolved around a lively physics teaching fair, where all countries had the opportunity to present their methods, ideas, experiments, books, projects, etc.. Participants met in workshop groups, over three 90 minute sessions, focussing on a wide range of issues, to identify problems in physics teaching and understanding and to propose recommendations for future improvement. The full reports of the workshop groups are presented in this booklet. Throughout the week, inspiration was provided by a series of presentations, suggesting different ways in which physics might be taught, and a number of entertaining performances, which literally put physics on stage.

For a colourful overview of the Physics on Stage festival, see the Executive Summary document, available from: Helen Wilson,
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[1] *Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, The Netherlands, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, United Kingdom.*

"The Crisis in Physics Education"

Keynote address at the Opening of Physics on Stage, given by John L. Lewis of the European Physical Society

The speaker began with two examples of recent trends. The first was taken from a report published by the European University Physics Education Network (EUPEN) which showed how the number of first year students studying physics in German universities was about 10,000 in 1996, but was now under 5000. His second example showed how, over a six year period, the number of physics graduates training to be teachers in the UK, had fallen from 568 to 181, and this year was even less.

"Other examples I might have quoted include the shortage of students to fill teacher training places in Sweden or the decrease in physics students in the United States. But it is not horror stories that are needed. What are needed are precise figures explaining whether there is a crisis throughout Europe, investigation into how serious it is and identification of the causes – and this is the reason for the 'Mapping the Crisis' workshop at Physics on Stage.

I am anxious not to give the impression that nothing is being done about the crisis. The EU set up an important colloquium on attainment in physics at 16+ at Cork in Ireland in 1998. In September last year the European Physical Society held a Seminar in Malvern in the UK on 'Securing the Future of Physics' to consider the problems. It was attended by most of the Presidents of Physical Societies around Europe and led directly to the establishment of a new European Physical Society Division for Education, with equal status to the other divisions. And now the EU is supporting this remarkable Physics on Stage festival in CERN to promote physics and physics education. I hope that the outcome will be more than the pleasure of seeing good experiments well done: I would like to see some major thinking about the crisis, if it exists."

The speaker then went on to consider the evolution of physics education throughout Europe over the last half-century: "When I was at school, physics was in water-tight compartments: heat, light, magnetism, electricity, and sound when you had time for it, which you usually did not! I learnt definitions and I learnt formulae, which students wrote on the back of their hands before going into exams. I did routine, standard experiments with standard apparatus. By remembering those formulae and being able to describe the experiments for measuring the thermal conductivity of good and bad conductors, I got to Cambridge University - but there had been none of the fun of doing an investigation. The emphasis was on the content of the syllabus which was essentially factual.

The beginning of change came with the Physical Science Study Committee in the 1950s - the exciting innovation in the United States following the launch of Sputnik. The Americans could never understand why the Europeans did not all adopt their course: the reason was that it was a one-year course intended for American High Schools, whereas most of us wanted physics courses which extended over several years of schooling.

What a refreshment PSSC was. There was a great increase in personal involvement by the pupils and a great increase in experimental work. What we all did in Europe was to pinch their good ideas and incorporate them into our own courses. I always admired their microbalance to find the mass of a fly. Very simple apparatus, which pupils could make themselves with a drinking straw. But how could it be calibrated? How could it be made more sensitive? It raised questions.

Thus began the era of development projects throughout much of Europe. Through resources provided by teh Organisation for Economic Co-operation and Development (OECD), work was initiated in most of our countries. Personally, I was involved with Nuffield physics in the UK. The change can be seen in the syllabus: no longer water-tight compartments. The syllabus was now a fabric of knowledge in which one part was seen to be linked with others.

There was a reappraisal of objectives. We believed in the saying "Hear and Forget, See and Remember, Do and Understand." Students did physics. There was a move away from 'just facts' to the process of science. And what a remarkable thing when 12-year olds could themselves make their own first atomic measurement, measuring the size of an oil molecule. This brings us to an important question: what should be the content of a physics course today? This is also put to you in the workshops.

There are important questions for you to consider. Should physics be a compulsory component of every national curriculum? What level of mathematics is necessary? Remember that the amount of mathematics often puts off many pupils. What part should be played by experimental work? How much modern physics should be included? We need your views.

There is also the question about the age at which science education should begin. We have an important workshop to consider the place of physics in primary education, in order that we can pass an opinion to the EU.

Returning to the history... Physics education in Europe was getting more interesting in the 60s and 70s. Was all well? Sadly the image of science was not good. We had moved from pure facts, and had come to consider the processes of physics. But we were neglecting the importance of people. The realisation that we need to relate physics to society led to the next fundamental change. There have been some notable courses on Science in Society, particularly in the Netherlands and the UK, and it is now a requirement that science syllabuses in the UK must consider social, economic and environmental issues as well as the science.

We were not always successful. These are some genuine student misconceptions:

- "Hydro-electricity is the safest form of electricity because it is mainly water."
- "A.C. is more dangerous that D.C. In D.C., the current goes straight through you. In A.C. it keeps going backwards and forwards."
- "Gas is the cheapest form of electricity."
- "Gas is dangerous if intoxicated."
- "Accidents cause death which it takes years to recover from."
- "Euthanasia is not popular with older people."

One important thing is to give a feel for units. A thought experiment: suppose you give a car of mass 1000 kg car some gravitational potential energy equal to one unit of electrical energy (1 kWh). How high will the car rise? Of course you will all get it right if you get out a pen and paper and think about 'mgh'. But what feeling do you have for the answer? 4 cm? 4 m? 40 m? 400 m?"

The speaker made a final plea: "There are serious public misconceptions that science knows all the answers; that science is always right or wrong. Should we be giving more attention to the limitations of scientific knowledge in our teaching and bring out the uncertainties?

It would be good to realise that what was a correct description of an atom pre-1885 would get no marks in an exam after 1895; that the "plum-pudding" model would get no marks after 1910 when the nuclear model took its place. Then came the work of Bohr, which was subsequently replaced by a quantum mechanical model. The part that models play in Physics is important. The nature of science should be part of the training."

The speaker finished with an experiment to demonstrate fission, for the sheer fun of doing it in CERN. He used arrays of matches to show how a chain reaction can have explosive effects. Fun, he claimed, should always be part of the teaching of physics - as he hoped Physics on Stage would prove.

The European Physical Society has produced a series of biographical posters to show the part that various people have played in the development of physics in all our countries. These are available from: European Physical Society, Rue Marc Sequin 34, Mulhouse, France.

Workshop 1: Mapping the Crisis report

Leader: Wubbo Ockels (European Space Agency)
Rapporteur: Helen Wilson (European Space Agency)

The workshop began with a comparison of the current status of physics education in the 22 participating European countries. Common problems were identified through statisitical and anecdotal evidence in several areas. Recommendations as to how the situation could be improved are listed in italics. Participants selected the six that they considered to be most important as the key recommendations.

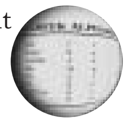
Recommendations

1. Introduce a reward system for teacher training schemes, supported by industry and the scientific community, which highlights teaching skills
2. Organise a lobby to boost the image of physics and which would ensure that lack of money is not adversely affecting schools.
3. Introduce physics into the mainstream (e.g. television, role models) to increase awareness of the connection between physics and daily life.
4. Increase political awareness of the problems raised at Physics on Stage.
5. Make physics lessons more fun and less mathematical for the majority of students.
6. Increase awareness that people trained in physics are very employable, in many areas of society.

Teachers (primary)
The majority of European Primary School teachers have a lack of science training – this is often responsible for demotivating curiosity in children at the age when they are naturally inquisitive.

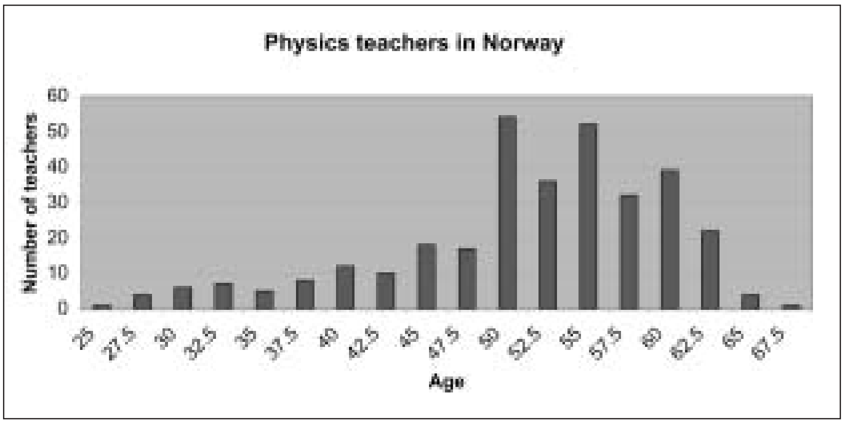
Science equipment and training should be made available for primary school teachers. Time and resources must be set aside.

Teachers (secondary)
The most urgent problem in secondary schools is a lack of physics teachers, brought about by three key factors:



1. few recent physics graduates are training to be teachers,
2. teaching is no longer regarded as a life-long career,
3. many established teachers are nearing retirement age.

In Ireland, only 16 graduates went on to become secondary school teachers in the academic year 1998/99. In the United Kingdom, the number of teachers has decreased by approximately one third over the past ten years.



This graph shows the age of physics teachers in Norway - the majority are close to retirement age, with few new teachers to replace them. This situation is found in many European countries.

Source: Carl Angell, University of Oslo, Norway carl.angell@fys.uio.no

The lack of physics teachers in schools has become a 'viscious circle' - in many schools with few or no physics teachers, physics is taught by teachers with no physics background and little enthusiasm for the subject; this affects the interest of the children in physics as it is not made exciting or explained clearly to them; this leads to fewer children studying physics to a higher level; and therefore fewer new physics teachers.

↗ few new teachers ↘

low number of physics graduates

physics taught by non-physics teachers

↖ children not interested in physics ↙

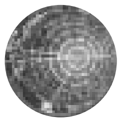
A recommendation as to how the circle could be broken takes into account the additional problems that motivation in the European teaching community is low and it is strongly felt that good teachers are not rewarded:
Introduce a reward system for teacher training schemes, supported by industry & scientific community, highlighting teaching skills.

University Students
Across Europe, there has been an increase in the total numbers of university students in recent years, but in many countries there has been a significant, relative decline in numbers of students choosing to study physics. This has led to a strong decline in the numbers of students going on to train as physics teachers.
Increase the amount of active learning – make learning fun.
Get organised – form a lobby to boost the image of physics and ensure that lack of money is not affecting schools badly.

Male : female ratio
There are consistently more men than women in Physics, from the level of secondary school onwards. (For more evidence of this, see the 'Women in Physics' report.)

Public Opinion
The positive reaction of the general public to scientific exhibitions, fairs and demonstrations is in contrast to the poor image of scientists and low status of science teachers in society.

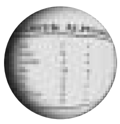
Make people more aware of the connections between physics and daily life by:
- *stressing the relevance of physics in solving world problems*
- *placing physics into the mainstream (eg. TV show, role models)*
- *stimulating the exchange of successful 'public understanding of science' projects*



Involve institutes, laboratories and industry in public awareness efforts, since they would benefit from increased public interest in their activities.

Differences across countries and regions
Delegates from eastern and western European countries had much in common with each other, as they all felt that teaching had a bad image and was viewed as a badly-rewarded profession. However, Eastern European delegates felt that their countries suffered from the additional problem that, due to poor economies, good graduates can easily earn more by moving to western countries, and therefore a higher loss of expertise is noticed.
An Eastern European delegate reported that a key reason for students not choosing physics is parental pressure to study a subject thought to lead to a financially rewarding career, such as Information Technology.
The general problems outlined above are not without exception. One delegate pointed out that France suffers no shortage in numbers of students going on to teacher training because teachers are government-employed. Further research into why some countries do not perceieve the same problems as others would surely be very valuable in solving the current crisis.

The infuence of politics on teaching problems cannot be ignored.
Increase political awareness of the problems.



Curricula
The level of choice available in school curricula has a major influence on student numbers. Schools where physics is compulsory produce a greater number of students going on to study physics at university than those where physics is optional.
Make physics compulsory, but with appropriate support to schools.

Some of the delegates felt that the rigidity of the curriculum forced teachers to teach their students how to pass the exams, rather than how to understand and appreciate physics. It was felt that a 'two-stream' approach would be beneficial, allowing students with a particular interest to explore the subject more deeply, but also providing for the majority of students, who might be put off by the 'difficult' mathematical parts of the curriculum.
Make physics lessons more fun and less mathematical for the majority of students.

University entrance requirements for physics courses are lower than those for similar subjects (e.g. engineering, information technology) due to lower demand. Some students interpret this as meaning that physics is an undesirable subject for further study.
Form applied physics courses (eg. computer physics) and increase awareness that physicists have a strong skills set, useful in many different careers.

Job market – education relationship
Physics graduates are often lured away from careers in scientific research and teaching by high-salary positions in banks, the stock market, information and communications technology, industry, etc... These industries have a high demand for people with a physics background, due to the logical approach to problem-solving that physics graduates possess. However, they do not seem to make a corresponding investment in education.

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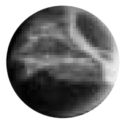
- Education and Training Statistics for the United Kingdom 2000 http://www.dfee.gov.uk/statistics/DB/VOL/v0211/index.html
- Statistics from the American Institute of Physics about Women in Physics (2000) http://www.aip.org/statistics/trends/highlite/women/women.htm
- A good resource of physics online courses can be found at www.boxmind.com



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Workshop 2: Physics in Primary Education

Leader: Rosemary Feasy (United Kingdom)

Session 1 – Summary Points

- Education prepares children for life so that they can make their contribution to society.
- Science education is an essential part of this preparation and should begin as early as possible.
- Young children all over Europe enjoy science.
- We must not underestimate their ability and their potential to think and work scientifically. They deserve and demand the support of creative science education from the earliest age.
- Children should be engaged in science that is challenging and fun.
- Science education should start as early as possible: in the home and nursery, at kindergarten and then at the beginning of formal schooling. Science education should be seen in terms of life-long education, beginning from infancy and continuing throughout the rest of life.

Recommendations

- All children in the European Union should have access to science experiences from the earliest age, that is, at home and from kindergarten to the age of 12 and onwards.
- All teachers of young children should have access to professional development in science education.
- The EC should set up a 'Virtual Resource Centre' based around an internet site.
- A European Association for Young Scientists should be created to provide opportunities for children to engage in informal science activities at home and in school.
- All European Research Centres should have an Education Division.

Science is an essential part of education because:

- It offers children a wider understanding of the world and of themselves.
- It helps children to develop a better appreciation of science in everyday life.
- Access to science education enables children to make wider career choices.
- It provides a reservoir of talent for business and industry, at all levels.
- It helps to develop citizens of the future who are better informed to make judgements about technological and scientific advances. They are therefore 'enfranchised' and able to take part in democracy.
- It helps to develop the understanding of individuals about basic science and evidence on which personal decisions can be made, regarding, for example, health and environmental issues.

The following ideas were discussed and are listed as some of the key issues from initial discussions about science education and in particular the place of physics in science in the education of young children.

- Children should have a range of experiences in science.
- Science education should develop children's skills.
- Science education should develop children's thinking: it should encourage children to be critical.
- Physics in science should be placed in everyday contexts and should encourage children to use all the senses.
- Teachers must encourage children to ask questions, teachers should not explain everything.
- Teachers should build on children's experiences, whether they be formal experiences in school or informal ones from home and everyday life. Teachers should then develop those experiences to help move the children forward.
- Teachers need to appreciate that there are different ways of learning.
- Teachers of older children should take note of the experience and learning of younger children.

- Teachers need support in developing their personal understanding in science, because many of them do not have good science backgrounds or understanding of how to teach science.
- Many teachers have a negative attitude towards science: this should be challenged.
- Types of assessment used should be varied according to the topic, the needs of the individual, etc.
- Children should be encouraged to record and communicate their science in different ways.
- Science is a rich source of development for language and maths. Conversely, science also requires good levels of literacy and numeracy.
- There is a need to encourage positive attitudes towards science, especially physics.
- A recommendation emerging from the first discussion is to establish a network to exchange experiences between teacher-trainers across Europe.
- We must remember that children enjoy science!

Session 2 – Summary Points

- Challenges facing science education for young children:
- The level of teachers' knowledge and understanding in science/physics.
- The level of understanding about children's learning and teaching approaches.
- Teachers' attitudes towards physics are often negative and stereotypical.
- Teachers need to be trained to know how to encourage children to think and work scientifically.
- Physics should be presented to young children in appropriate contexts.
- It should be recognised that education prepares young people for citizenship. : The 'adults of the future' need to be informed about scientific issues.
- Teachers need help to support children in developing different ways of recording and communicating in science. Teachers should not rely only on the written word.
- Teachers should consider physics in the home and local environment and make links with everyday life when teaching physics in science.

The following are the recommendations that this group put before the conference:

Recommendation 1
All children in the European Union should have access to science experiences from the earliest age, i.e. at home and from kindergarten age to the age of 12 and beyond. These science experiences should:

- be fun,
- be motivating,
- be practical / hands-on,
- develop critical thinking skills,
- build on what children already know,
- be placed in relevant contexts that take account of the culture of young people,
- develop positive attitudes in young children towards science.

Recommendation 2
The EC should ensure that there is parity of quality of science education across Europe for young children. All teachers of young children (up to the age of 12) should have access to professional development in science education. This should include teachers training to enter the profession, as well as established teachers.

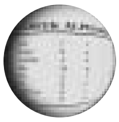
Recommendation 3
The EC should set up a 'Virtual Resource Centre' based around an internet site. This Centre should allow teachers of primary science across Europe to:

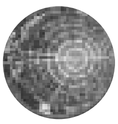
- exchange and share experiences,
- exchange ideas and materials on teacher pre-service and in-service,
- share national curricula and national initiatives,
- offer a mailing list, bulletin board, discussion forum, etc.

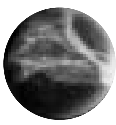
The Centre must be adequately funded and managed and have the facility for translating material into a range of European languages.

Recommendation 4
A European Association for Young Scientists should be created, which:
- offers opportunities for children to engage in informal science activities at home and in school,
- offers opportunities for the local community to join in science activities,
- offers a range of awards to children and local communities,
- helps to raise the profile of science with children, parents and the local community,
- encourages creativity in science from an early age,
- encourages parents and the local community to take part in science activities.

Recommendation 5
The Physics in Primary Science working group is concerned that the European Union takes advantage of facilities that are already available across countries. There are a number of Joint European Research Centres: each of these should have an 'Education Division' which:
- links the scientific community with education across the primary years,
- provides a focal point for teachers within that country and across European Countries,
- develops primary science teaching e.g. Centres of Excellence,
- facilitates the exchange of ideas and materials in primary science,
- uses the facilities and frameworks for working that are already available in those Centres.







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Workshop 3A: Physics in Secondary Education

Leader: Jean Collins (United Kingdom)
Rapporteur: Tobias Kirschbaum (Germany)

Bringing together different nationalities – Introduction to the Workshop Process
The unique opportunity to discuss with colleagues from countries around Europe at 'Physics on Stage' was used to the full in this workshop. Reports and an exchange of experiences and curriculum requirements in various countries formed the basis of the itinerary.

The first notable feature was that many experiences were common to us all. The second highlighted the many differences and great variety of criteria expected by the governing bodies of the respective school systems. The third and final point, discussed at length, was our area of common ground, namely the need to educate everyone to the relevance of Physics in this modern Scientific Age.

With these three points in mind the workshop members went on to develop their set of recommendations, aiming to be general enough for all members and precise enough to be helpful for development by governing bodies.
Using the unique opportunity to bring together teachers from countries all over Europe at Physics on Stage, the workshop started with reports and an exchange of experiences from the countries the workshop members work in.
The first aspect to become apparent was that many experiences were similar in each country. The second aspect showed the great variety and the many differences of the respective school systems. The third aspect, however, was most surprising:
Though coming from different backgrounds and bringing in different characters and ways of teaching, the results from successful teaching approaches led into one direction: It is most important to show the relevance of physics to everyday life. As soon as this was taken into account, the interest of students increased massively.
Having found this rough direction very soon, it was then the task to put this into a set of recommendations, both general enough for all members and precise enough to be helpful for future work.

Recommendations

- Learning should be based on everyday life in contexts highlighting physics, past, present and future.
- Students' learning should incorporate experimental, theoretical, mathematical and Information and Communication Technology (ICT) skills.
- A range of teaching methods must be used to enable students to become independent learners.
- To provide appropriate learning environments, teachers' skills need regular updating.
- Government criteria for physics teaching should provide enough flexibility in course design to allow context-based teaching.
- Adequate equipment, sufficient teacher training and the promotion of physics must be financed.

Taking in a European perspective – The Workshop Recommendations
Having discussed different formulations of the recommendations in the course of the workshop, the members finally agreed on the following six recommendations. As each recommendation had to be both precise and short for auditorium presentation, they need elaboration to specify all details included.

Recommendation 1: Content
Learning should be based on everyday life in contexts highlighting physics, past, present and future
Today's physics teaching very often is based on university physics transferred to a lower level. These traditional course designs, however, have proved to be unsuccessful in maintaining the interest and motivation of our students.

As personal experience shows, physics lessons should therefore be based on contexts that not only show the importance of physics for students' everyday life but also include findings in recent physics. By working on topics like "Physics in Medicine", "Environmental Physics" or by including aspects of Astronomy or the History of Science into coursework, students are more likely to find physics a highly interesting subject to choose and study. This especially seems to apply to physics taught by teachers who are fascinated by the topics themselves.

Recommendation 2: Skills

Students' learning should incorporate experimental, theoretical, mathematical and Information and Communication Technology (ICT) skills.

Whereas traditional approaches very often focus on mathematical calculations, a wider range of different skills should be fostered intensively. By taking physics, students should gain insight into the various ways scientists use to gain and interpret data and thus to widen their knowledge about the world we live in.

As talking about and discussing physics is a necessary part both of this process and the advancement of public understanding of science, presentation and communication skills have to be trained explicitly. Using information technology must become an integral part of physics coursework as well.

Recommendation 3: Learning Environment

A range of teaching methods must be used to enable students to become independent learners.

As each student has different ways of learning and understanding, physics teaching should provide a wide variety of teaching methods. Whereas the teacher was the focal point in traditional course design, he now should help his students to work independently, co-operatively and in an increasingly self-organising way.

This can be achieved by including e.g. problem-solving approaches, field trips, 'minds-on' experiments and models of different kinds into everyday coursework. However, it seems unreasonable to assume that there is only one correct approach.

It is the variety of methods used in one class that sets up a rich and thus productive learning environment.

Recommendation 4: Teacher Training

To provide appropriate learning environments, teachers' skills need regular updating.

The changes in physics teaching suggested here require teachers who have learned to teach in the ways mentioned.

Therefore, governments have to supply sufficient means of both initial and in-service training for teachers. These seminars should cover different methods as well as training on experiments and the use of information technology. Above all a continuous exchange of experiences among physics teachers should be established both on national and international levels. Fairs like Physics on Stage could serve as a model for this.

Recommendation 5: Statutory Guidelines

Government criteria for physics teaching should provide enough flexibility in course design to allow context-based teaching.

Teaching context-based physics in the way outlined here can lead to a deeper understanding of science and to a greater scientific literacy among the students. However, such an intensive work requires more time.

Therefore, curricula and syllabuses have to become more flexible: the compulsory core should be reduced to enable teachers to include context work into their course designs. The remaining core has to be adapted to the actual number of lessons taught in the respective schools and levels. It might prove necessary to increase the total number of physics lessons, too.

Recommendation 6: Financing

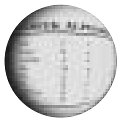
Adequate equipment, sufficient teacher training and the promotion of physics must be financed.

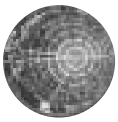
Throughout Europe, governments talk about the necessity to promote science because the number of scientists and engineers is constantly going down.

Applying the recommendations so far seems to be one possibility to overcome these problems. However, this can only be achieved if schools, teachers and students are supplied with sufficient financial resources to equip the physics departments and to organize and run the teacher trainings mentioned in recommendation 4.

Adapting the European perspective to national requirements – Sketching the next steps
The recommendations stated above are necessarily general. Nevertheless they show that throughout Europe similar experiences have outlined an approach to physics teaching which is likely to improve the present situation.
Having sketched this approach and its requirements in a European perspective, the details now have to be adapted to the national requirements. This process of specification should be an immediate follow-up to this workshop.

Additional materials and links
As many members of the workshop have done some research on the topics mentioned, quite a few materials have been published. The sources given below are by no means complete but only serve as examples for the very active state of the discussion.
Ölme, Alf, (2000), "View on the physics curriculum beyond 2000". *Phys. Educ.* 35(3), 195 – 198.
Woolnough, B.E. and others (1997), "Factors Affecting Students Choice of Career in Science and Engineering: parallel studies in Australia, Canada, China, England, Japan and Portugal". *Research in Science and Technological Education.* 15, 105 - 121.
The European Physical Society has also published a survey of different national syllabuses in the internet: http://www.eps.org. This address could easily serve as a starting point for further investigation.





Workshop Participants

Austria	Heimo Hergan, Peter Oswald, Rudolf Ziegelbecker
Bulgaria	Vanya Angelova, Victor Ivanov
Czech Republic	Irena Koudelkova
Germany	Carl-Arthur Feldmann, Tobias Kirschbaum, Jürgen Miericke
Hungary	Sandor Csajagi, Andras Mester, Laszlo Zsudel
Netherlands	Gert Schooten, Kate Smith, Robert Wielinga
Poland	Jerzy B. Brojan, Zofia Golab-Meyer, Aleksandro Milosz, Eva Strugala
Portugal	Pedro Pombo
Sweden	Eva Berglund, Ove Finnhult, Alf Ölme
United Kingdom	Jean Collins, Kathleen Davies, Ann Marshall, Margaret Parkinson

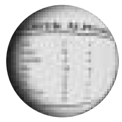
Workshop 3B: Physics in Secondary Education

Leader: Marie-Louise Zimmermann-Asta (Switzerland)
Rapporteur: François Mireval (Switzerland)

The workshop began with several presentations, given by some of the participants:

Xavier Prado	- Introducing the theory of relativity to secondary schools in an entirely visual way
Albert Bramon	- The simplest experiments that pupils can do at home
Carlos Sanpedro	- Science teaching and pupils' ideas. The Axarquia working group.
François Mireval	- APA Apprentissage Par l'Autonomie (Distance Learning)
Yvonne Verbist-Scieur	- Original eduational packages
Pablo Nacenta	

Following the presentations, we discussed the key issues that affect physics in secondary education. The participants felt that it is important to teach physics to everybody, as physics is an important part of culture. All students should be taught physics: efforts must be taken to develop a scientific culture amongst students and raise their levels of interest.



Direct experience is very important in learning physics. Physics lessons should draw links with technical objects of everyday life. Teachers should endeavour to develop children's mental speculation: let them play with physics and investigate all possible fields for themselves. Physics teaching should be adapted to the experiences of the general public and presented in easily-accessible contexts. Students should be taught useful physics to ease their progress from youth towards responsible citizenship. Physics leads to open-mindedness.

Recommendations

- It should be recognised that Physics is absolutely necessary to everybody, because it is a part of today's culture.
- Physics teaching must develop a way of thinking for the majority of students that will never become scientists.
- Physics teaching should provide meaningful explanations to students all over the world, so it must be linked to reality.
- Physics teaching should be tuned to different school levels and different interest groups.
- As physics is an experimental science, teaching requires adequate human and material resources, reasonable class sizes and adapted schedules to develop different aspects of scientific methods.
- Teachers of physics require skills in physics, didactics, pedagogy, and an open-minded attitude. Thus, teacher training in accordance to those objectives is essential.

Physics is an experimental science, but one must understand the underlying theories. Experimental work can be carried out with cheap material - there should be an evaluation of current practical work to find the most effective approach.

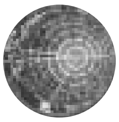
Physics is closely linked to mathematics and the use of computers. Interdisciplinary work should be encouraged to give a wider view of reality, which can be rather complex. Students should be allowed to develop autonomy as they are learning. All paths are good ones, as long as the final objectives are reached.

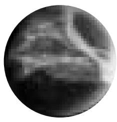
The group though that secondary school pupils can be divided into four groups, regarding their attitudes to physics:

- those who want nothing to do with it,
- those who have some knowledge but will not be scientists,
- those who will become scientists,
- those who have learning difficulties.

Physics must be taught for those students who will never become scientists, as these represent the majority. For this group of people, educational novelties must be found to retain their interest.

Secondary (and for that matter, primary) school teachers are often insufficiently trained in physics. Teachers concentrate on ploughing through the maths, rather than convincing the students with physics. Students do not gain a good appreciation of the fact that physics is linked to reality but is not realistic (the progression from experience to model). More effort should be made to train teachers and more time should be allowed to teach physics.





Workshop Participants

Belgium	Jean-Marie Kayls, Yvonne Verbist-Scieur
France	Marie-Christine Baurrier, Norbert Calvat, Monique Goffard
Spain	Albert Bramon-Vives, Mariano Merino, Pablo Nacenta, José Pastor, Xavier Prado, Carlos Sampredo-Villasan
Switzerland	Didier Chatellard, François Mireval, Marie-Louise Zimmermann-Asta

Workshop 4: Physics and Public Understanding

Leader: Katarina Teplanová (Slovak Republic)
Rapporteurs: Brenda Keogh (United Kingdom), Heike Look (Germany), Katie Gallagher (Ireland)

Method of work
The work of the group was divided into three parts:

1. Mutual introduction of participants, their experience with public understanding of physics and expectations from the workshop.
2. Information about Malvern seminar results, discussions in two parallel sessions concerning communicating science requirements and the roles of institutions communicating science.
3. A common discussion to summarise the workshop group recommendations.

Ideas of 23 participants from 15 countries[1] were written in bullets by three reporters[2]. Every participant received them after the sessions. Here are the main points arising from the partial discussions that the participants assume as very important:

1. The State of Public Understanding of Science
The success and importance of science are themselves not enough to be put into evidence by the general public.
Science is not generally seen as a part of mainstream culture. Physics and chemistry are "negatively charged" (scientific language, atom bomb, nuclear power plants, pollution etc.). People tend to be afraid of science rather than attracted to it. Their motivation towards science and technology is, due to the ways of science introduction in schools and the media, poor. They believe that science is beyond their sphere of interest. Knowing nothing about science is often not viewed as a bad thing, especially by girls.

Scientists cannot just assume that the public has no scientific understanding. Many people have detailed knowledge of some aspects of science – for example, the science involved in motor engineering or wine making. There are different degrees of interest and understanding amongst the public and amongst the scientists. Do most scientists have any real information about what the public does or does not know about scientific topics?

Recommendations

Universities, research centres, science industries and physical science organisations should:
- Collaborate to provide courses in science communication for journalists, policy makers, scientists, science students, etc..
- Bring physics to the people through the establishment of community-based science centres and outreach programmes.
- Sell physics to the media by making it accessible and relevant to the public and through linking physics to other disciplines.
- Look for effective ways to respond to people's needs and interests.
- Value and expect the communication of scientific research.

And finally:
- All the participants of this workshop realise the importance of teaching science in general, and physics in particular, to everybody, and therefore each of us will try to do at least one thing to communicate physics to public and will report on it at the second "Physics on Stage" festival.

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[1] *of different experience with communicating science from universities, high and secondary schools, physics institutes, science centres, media and communication with industry*

[2] *Brenda Keogh from Manchester Metropolitan University, Heike Look from Dieburg high school in Germany, Katie Gallagher from Trinity College in Dublin*

There are not enough institutions responsible for public understanding of science, such as interactive museums and science centres focused professionally on public relations of science, non-formal lifelong learning, research into public understanding of science, questions that aid learning and motivation, support of schools by present science knowledge, training for teachers etc.

There is a contrast between learning science in science centres and learning science in schools. School is an important source of science learning but not the only source. In some countries there do not seem to be enough science centres. In schools, as well as for the public, only some fields and aspects are commonly promoted (for example astronomy, classical mechanics), thus missing the everyday experience and relation to Nature and environment.

2 a) Communicating science requirements

- Value what the public do know rather than viewing what they do not know as a deficit from what they should know.
- Communicate to the public where the answers to scientific questions might be found.
- Ensure that children have a positive view of science from a young age.
- Ensure education in science communication at universities.
- Development of local science centres and libraries for the public that are easy to get to and make it easy to understand science.
- Review the role of science centres as a link between teachers and scientists.
- Influence the media to represent science and scientists more appropriately.
- Encourage local industry to communicate science to local communities.
- Interdisciplinary science projects using complexity and arts to communicate science (for example science teachers working with teachers of other disciplines).
- Extraordinary events (interactive exhibitions, festivals, competitions, lectures of famous physicists, open days at universities and science institutions).
- Special public venues to communicate science (concept cartoons, posters, science theatre).
- Mobility, travelling exhibitions, exchange and dissemination of learning aids.

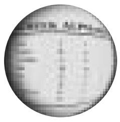
2 b) Roles and activities of institutions and individuals in communicating science

- **Museums and science centres** should
  - interest people in science through unique personal experiences;
  - focus on science in an interdisciplinary way;
  - introduce aspects and different approaches of science not usually presented;
  - address current issues and present possible answers;
  - address all levels of knowledge;
  - show the public how science affects their lives;
  - should collaborate with universities;
  - play an active role as the pilots of new educational concepts;
  - play an active role in establishing networks of young scientists;
  - have outreach activities such as fairs, partnerships with TV and radio broadcasters, etc.

- **Universities and research institutions** should:
  - contribute more to the public understanding of science;
  - collaborate with science centres;
  - create science communication for journalists, science research students, teachers and artists;
  - use older students to teach younger students;
  - educate young scientists in communication, encourage graduates to go into media;
  - make it more attractive for scientists to publish in public media (instead of exclusively in scientific and technical journals);
  - value and support the communication of science as part of any research activity (allocating resources accordingly);
  - give science teachers experience in laboratories.

- **Public Media** should:
  - propagate more science (scientific discoveries, hypotheses, tasks, methods etc.) than science fiction (Hollywood etc.);
  - invite scientists, especially young scientists, to present their work to the public;
  - prepare discussions between science students and non-science students on science problems;
  - introduce general problems (environmental, medical etc.) in discussions with scientists;
  - consult scientists on the presentation of pseudo-science (astrology, etc.);
  - always cover science in the daily news;
  - elaborate science topics with the same care as art pieces;
  - balance the programme structure so that science and science education play a significant role.

- **Individual scientists** should:
  - try to give responses to the people's needs and questions as part of making science more humanised, more part of everyday experience and democracy;
  - represent themselves in ways which are accessible to the public and use everyday language in public communication;
  - look for ways to communicate science through links with other disciplines (arts, environment, etc.);
  - recognise that public interest in science may lead to science funding through policy makers;
  - recognise that science funding will not necessarily lead to public interest if scientists are not sufficiently involved in the public understanding of science.



- **National Physical Societies** should:
  - introduce science communication as one of the main tasks of the physics community (through the internet, direct presentations at conferences, seminars, etc..);
  - support public understanding of physics in interdisciplinary contexts;
  - encourage famous researchers to participate in public understanding programmes, lectures, political discussions, etc..

European Physical Society should:
  - create a coherent resource of public understanding of science materials, supported by the EU.

Governmental institutions should:
  - promote public outreach of science through science centres, local industry, libraries, and public broadcast of TV and radio programs.

All the participants, of this workshop realise point out the importance of teaching science in general, and physics in particular, to everybody, and therefore each of will try to do at least one thing within her/his own context to communicate physics to public and will report on it at the second "Physics on Stage" festival. I offer the Schola Ludus address for the purpose of collecting the reports:

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Czech Republic	Karel Rauner
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France	Dominique Cornuejols
Germany	Manfred Euler, Lutz Fiesser, Heike Look, Otto Lührs, Burkard Steinrücken
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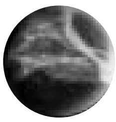
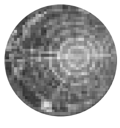
Italy	Roberta Antolini, Umberto Donzelli, Antonio Evoli, Luisa Follini, Silvia Vannucci Giromini
Netherlands	Cathalijn Drucker
Poland	Jerzy Jarosz, Tadeusz Skoskiewicz, Ireneusz Strzalkowski
Portugal	Ana Campos, Maria Sousa
Slovak Republic	Katarina Teplanová
Spain	Fernando Jauregui, Jorge Mira, Christian Wagner
Sweden	Sven-Erik Viberg
United Kingdom	Brenda Keogh, Geoff Moore





Workshop 5: The Role of History and Philosophy in Physics Education

Leaders: Nicholas Witkowski (France), Jacques Treiner (France) & Anne Bedford-Brumfitt (the Netherlands)
Rapporteur: Jean-Louis Heudier (France)

The following issues were considered:
- What part should the history of physics play in physics education?
- How should physics education address the belief that science is either right or wrong?
- Should moral responsibilities be considered as part of physics education?

Recommendations

- The History and philosophy of science should be part of the training of physics teachers.
- Information about successful and unsuccessful uses of the history of science in teaching should be collected and made widely available.
- Historical and physical societies should be encouraged to collaborate.
- Through the history and philosophy of science, a more realistic image of science should be given. Tools should be developed to address social issues involving science.
- The history and philosophy of science should be used to clarify the relationship between the scientific world view and those from other fields of knowledge.

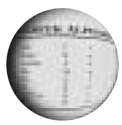
One of the main conclusions reached in this workshop is that the history of science is currently underused as a pedagogical tool in physics teaching. Most of the time, due to poorly informed teachers and lack of interest from the curriculum makers, some very short (and often unfair) biographies are quickly presented whenever time is left at the end of the lesson. It is in fact possible to teach physics without any reference to history, but all the participants of this workshop think that a clear and deep understanding of scientific notions can only be acquired through a good grasp of their history. This leads to a paradox, which Alfred North Whitehead duly recognised:

"A science which would forget its past would be lost. A science which would refuse to forget its past would be lost too."

Obviously, science teaching has forgotten too much of the past of physics. It would be irresponsible to teach physics only through its history, and in some cases very misleading: some parts of physics, such as quantum mechanics or relativity, are better taught without references to history, but other parts of physics, such as mechanics, optics or thermodynamics, obviously profit greatly from a bit of history.

There is much to be gained: not only better and more attractive teaching, but also a better understanding of the current scientific issues. That is why the history of science, and the philosophical views which go with it, are, we believe, one of the solutions to the current crisis of physics teaching.

History and physics teaching
Our first recommendation is to include a bit of history of science into the physics teachers' curriculum. This would certainly help to show how useful the history of science can be. There are a number of beautiful historical experiments that can be used in the classroom: Eratosthene's measurement of the Earth, the so called "Franklin's experiment" to measure the length of a stearine molecule, or Oersted and Ampère's experiments with electromagnetism are some examples among many others.



Starting from these experimental facts, it is often possible to grasp some of the "spirit of the times". What were the commonly accepted ideas in the days of Copernicus, Galileo, or Einstein? How was science related to arts, literature, politics and economy in various countries (European and non-European) at the time? These sorts of questions, we believe, are able to focus the physical enquiry onto firmer ground, and show that science has never been a purely utilitarian quest, but a deeply rooted cultural phenomenon.

Is it unimportant to know that Galileo's father was a musician, Newton was an alchemist, John Dalton a meteorologist and James Joule the son of a beermaker? Or could it help children to understand why Galileo was so good at measuring time, why Newton tried to apply to the microscopic world the laws he found that govern the movements of the heavenly bodies, why Dalton became interested in the nature of gas and Joule in the precise measurement of temperatures?

History of science is so rich with anecdotes, surprising characters and strange coincidences that it is perfectly fit for making a physics course much more than just equations and computing.

Physics and other disciplines
As a cultural phenomenon, physics can be linked to all the other disciplines, especially language (the prose of Galileo is marvellously clear and can be studied for itself) and history, which can successfully include a lot of technological and scientific references and be a part of joint projects.

This vanishing of scholarly disciplinary borders has to be encouraged, in order to show how physics is, and has always been, an essential part of our cultural world, and was much closer to the literary disciplines one or two centuries ago than it is today. The distinction between "alpha" and "beta", science and literature, is a modern and erroneous invention. Curiosity has no disciplinary limits, and the perceived mathematical barrier surrounding maths and physics is probably one of the main obstacles towards a good appreciation of physics at school.

The popular conception of exact sciences as either "right or wrong" ought to be challenged too: scientists do make errors sometimes, and understanding these errors can be very fruitful, showing how theories are slowly built by a community of scientists, and not, as the 19th century historians of science tried to show, by some clever geniuses touched by divine grace.

A more accurate image of science
History of science leads naturally to philosophy of science, ("Scientist" is a recently coined term which has replaced "natural philosopher"), and this is where another main benefit may come from, because science, today, is not only in the classrooms and is not only the science of the past proposed by the curriculum. It is on the news every day: the International Space Station, AIDS, mad cow disease, the Higgs boson hunt, genetically-engineered vegetables, the Greenhouse Effect, etc..

Pupils know how complicated the real scientific problems are, and find it difficult to relate these problems, their controversies and political or economical aspects, with the sort of "pure" science which is taught at school.

That is why it is necessary, especially at the secondary level, to give an accurate view of science, not an oversimplification. To present the good sides of science, and the less glorious ones. To give a fair report of history, not a childish or idealistic view. To show that scientific truth is not the ultimate truth, but one way of seeing things amongst others. To be a bit less assertive in our teaching... and more open-minded to the reality of science today and in the past, could lead us to being much more efficient.

One of the important goals of physics teaching, apart from the science teaching itself, is to give our pupils the necessary tools for coping with the moral and political issues at stake in the world today. They need these tools to understand the questions which every citizen of our scientific civilization has to answer.

Workshop participants

Belgium	Jacques Olivier
Bulgaria	Alexander Vavrek
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Germany	Davy Champion, Boris Engelson
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Italy	Giovanni Magliarditi, Carla Romagnino
Netherlands	Anne Bedford-Brumfitt, Tonny Hofstetter, Robert Wielinga
Poland	Wlodzimierz Natorf
Slovak Republic	Dalibor Krupa
Switzerland	Eric Lindemann

Workshop 6: Consideration of the Major Issues of Today

Leader: Adam Kovach (Hungary)
Rapporteur: Kerry Parker (United Kingdom)

The first workshop session was spent discussing the major issues and the relevance of physics education.

The need for sustainable development
We agreed that the main issue of concern to society is the problem of sustainable development. All societies are addressing the big questions, for example: should the consumption and demands of future societies follow the recent exponential growth – or should we take a different route?
The delicate balance of the World is being profoundly affected by human activities. How must we act to maintain the development route of mankind? After some debate about the need for nuclear fission, solar power, global warming, etc… we agreed that as physics educators we were not going to solve these problems in this workshop, but that we should concentrate on enabling future generations to address and solve these problems.

The role of physics and education
The children we teach now are the decision makers of the future. The knowledge and skills we give them will enable them to make, or not make, the right decisions. Physics underpins the new technologies, many of which may play a role in solving some of the problems of sustainability. However, all the delegates reported that society has an often negative attitude to physics, founded on a history of nuclear accidents, government cover-ups and the over-optimism of scientists in the immediate post-war years.

The physics curriculum
There has been a massive growth in new technology and information. Traditionally, education means the transfer of knowledge to future generations. But we have to teach students to apply science which hasn't been developed yet, because knowledge is advancing so fast! Thus skills are much more important in education than ever before. We are not only involved in imparting knowledge and skills, but also attitudes.

For effective communication we need to engage our students: the very gloomy, 'doomsday' scenarios described in some projections are a 'turn off' for many students. Some German colleagues have found that by encouraging direct action, such as by building machines with solar cells and encouraging energy-reduction methods, their students have been better motivated.

Nonetheless, students should have access to the true picture, as far as we understand it. We need to teach them how to find the truth amid the propaganda and emotive language.

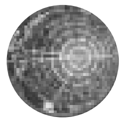
The second workshop session was devoted to discussions regarding the teaching of radioactivity and nuclear physics, especially with regard to nuclear power and waste

Recommendations

- It should be recognised that physics has immediate relevance in understanding and solving problems of sustainable development and growth.
- A curriculum should address the above issues and the immediate impact of physics on everyday life, based on a complex, interdisciplinary approach.
- The pace of research and the increasing availability of information calls for relevant and on-going teacher training.
- International cooperation should form an integral part of the development of curricula at local and national levels.
- Students and teachers should be given reliable information from a variety of sources, which is up-to-date and free from propaganda.
- Curricula should enable students to take reasoned decisions, weighing up evidence and risk in a social and economic context.

management. Most of the problems are interconnected and interdisciplinary. For example, radioactive waste and nuclear safety are linked to geology and hydrology as well as sociology, politics and finance. This must be taken into account when we consider the curriculum – we must have debate and cooperation between physics and other disciplines. In schools there are many possibilities to collaborate.

Curriculum Design
The nations represented at the workshop have very different patterns for the development of curricula: some teach physics as a separate subject, others have more general science courses; some nations teach science at an early age, whilst others introduce it later. Also, some teachers have an externally imposed National Curriculum, while other teachers have more flexibility. Within each system, teachers were able to cite good and bad practice. In general there was a feeling that teachers needed to be able to respond to the current news events so that students were not learning their science from badly-informed, emotive TV programmes and newspapers. Inter-disciplinary collaborations are also very important.



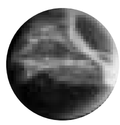
Risk assessment
Teaching the ability to analyse data, and form a rational decision was also considered essential. The link between cause and effect is often very tenuous in radiation protection. Students need to understand the impact of their actions and the limitations inherent in making predictions. It is vital that we tell the truth and do not pretend that “physics is good”, or that we can predict anything with 100% certainty!

Information sources
Finally we discussed sources of information. The web provides some excellent material, but it is often not in a very accessible form and may be difficult for students and teachers to find. Also there is a lot of poor, wrong, emotive and incorrect material on the web. Students need to learn to discriminate and have access to good, reliable material.

Recommendations
The final workshop was spent discussing the summary. Most delegates found a simple 6-point statement very useful:

Physics is vital to sustainable development.
We need these issues in the curriculum.
That requires teacher training,
international co-operation, and
good sources of information
to allow reasoned decisions.

The delegates unanimously endorsed these points and also were also very enthusiastic to meet again to continue this important work: the group recommends setting up a conference to look further at physics education and sustainability issues.



Workshop Participants

Bulgaria	Alexander Vavrek
Finland	Ilkka Koivistoinen
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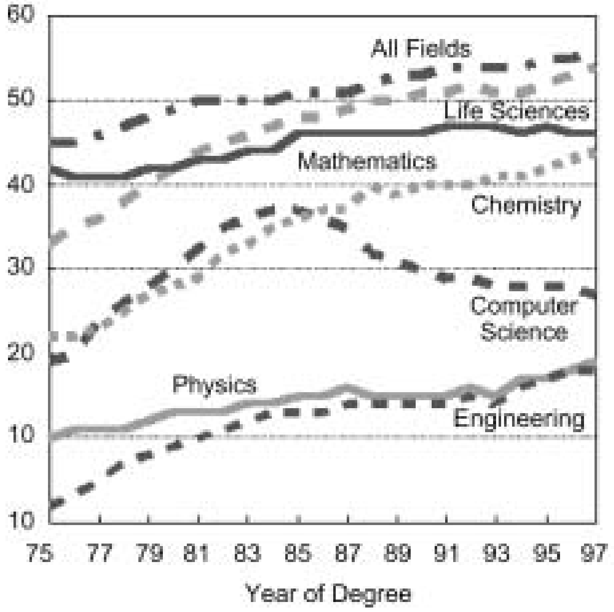
Germany	Ulrich Ernst, Paul Feltes
Hungary	Adam Kovach, Gabor Naray-Szabo
Netherlands	Egil Lillestol, Tim Scholten
Norway	Karl Torstein-Hetland
Poland	Jan Mostowski, Hanna Szyburska
United Kingdom	Kerry Parker

Workshop 7: Women and Physics

Leader: Cecilia Jarlskog (CERN)

The workshop had 15 participants, of which 3 were men. We began by considering some statistics from sources such as the American Institute of Physics and the European Union. These showed that:

- Women don't love physics (they avoid it happily)
- The physics environment doesn't love women.

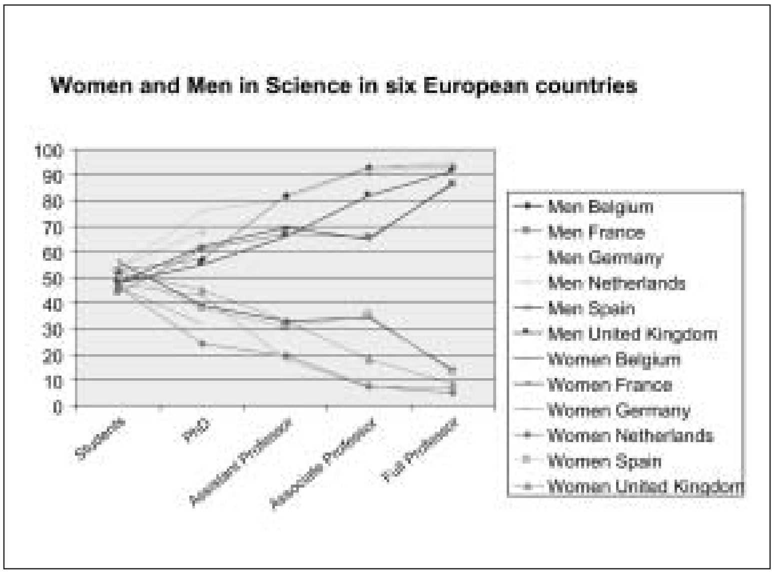


This graph shows the percentage of Bachelor's degrees in scientific fields earned by Women, 1975 - 1997

Source: Statistical Research Center, American Institute of Physics. Data from Mulvey & Nicholson, Enrollments and Degrees Report.

This graph shows the percentage of women and men in science in six European countries. The lack of women at the top levels cannot be explained by a lack of women in the corresponding undergraduate classes.

Source: 'Science Policies in the European Union: Promoting Excellence through mainstreaming gender equality - a report from the ETAN expert working group on Women and Science'.



The workshop group thought that these statistics were shocking. In a nutshell, there is a big difference in the way men and women appear on the science career maps; there are very few women towards the top of the academic hierarchy. This is actually true of all sciences and not just physics. Even in ‘soft’ science, men dominate at the top of the academic ladder.

Our conclusion was that there is plenty of subconscious discrimination against women in many countries. We suggest that all men and women be constantly reminded of this hidden danger.

Recommendations

- Gender awareness should be included in the education of teachers. Physics lessons should include physics that girls will like.
- Gender awareness is needed at higher levels in academia.
- Women with small children should be supported by academic institutions through the provision of childcare, job-sharing, part-time jobs, etc.

And some more radical suggestions:

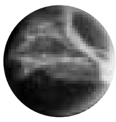
- Let girls start school one year earlier than boys.
- If measures to attract girls to physics fail, then teach them separately from boys.

We also suggested that academic institutions should take measures to help women with small children (childcare, job-sharing, part-time jobs, accepting the difference in ‘effective age’ between a man and a woman who has had children, etc.)

We then discussed the behaviour of girls and boys in school. It is well documented that girls and boys mature at different rates and have different behaviour patterns. The participants felt that girls often lack confidence, they think their work is not so important and that physics is not for them. Some girls even feel ashamed for being interested in physics!

The workshop participants felt that physics is the best vaccine against superstition and every child needs to be trained in basic physics. It is vital that teachers are sensitive to the issues mentioned above and take them into account when teaching physics. Girls are more interested in cultural, historical, humanistic, medical, and musical aspects of physics - in other words, topics that relate physics to everyday life. These aspects must be included in physics lessons.

We wish to see more female physicists in the media and more young girls expressing an interest in physics.



Workshop Participants

Belgium	Petra Rudolf
Finland	Jussi Kytömäki, Markku Säily
Germany	Sigrid Zwiorek
Greece	Merkourios Panagiotopoulos
Hungary	Anett Nagy
Italy	Vittora Massidda
Sweden	Ulla Siren-Peura
CERN	Cecilia Jarlskog

Workshop 8: Physics and Toys

Leader: Hubert Biezeveld (the Netherlands) & Rafael Garcia (Spain)
Rapporteur: Klaus Buschhüter (Germany)
Special guests: Louis Mathot (the Netherlands) and Jim Jardine (United Kingdom)

Hubert Biezeveld and Louis Mathot, authors of *Scoop*, brought part of their toy-collection, and Rafael Garcia Molina, professor at the University of Murcia in Spain and Jim Jardine from Scotland, author of *Physics is fun*, showed their favourite toys. Other participants also brought toys and showed some games and tricks from their respective countries. More than 200 toys were shown, ranging from traditional to present-day products, some of them cheap and others more expensive. We had a good time doing experiments with those toys and thinking about provoking questions related to the physical principles under which they work. So most of the time we behaved like pupils and students playing with interesting things.

It was nice to see that many toys and games have similar versions in different countries, which means that toys are excellent for communicating physics across language and frontier barriers. It was also interesting to see how many devices that could be used to introduce physical concepts are available in toy shops. Some of these toys and games can be prepared with very cheap materials, easily available in many homes and schools. Physics can also be used to invent or design toys, games and tricks.

Due to the different professional activities of the participants in the workshop, it was clear that toys can be used at all educational levels (from elementary school, to primary and secondary education and even at university), although their particular use depends both on the audience and on the message we wish to transmit.

E-mail addresses were collected with the purpose of distributing a document (prepared by Rafael Garcia-Molina rgm@um.es) containing references in which the use of toys and games for teaching physics are discussed.

In the third session formulated with short recommendations. As our conclusions about the meaning and the function of toys were created in a rather short time at the end of the workshop, the introductory questions from the workshop schedule (What role does 'play' have in learning physics? What kind of toys illustrate physical principles? How can physics be made fun? -Comparison of different experiences.) were not really discussed. But we organised a short debate, in which several questions were raised. The next paragraph shows a brief summary of some of these discussions.

Recommendations

- Make teachers aware that toys have a high motivating function: they provoke questions and lead naturally to investigations.
- Encourage teachers to join children in playing with toys and make learning fun.
- Toys and scientific understanding should be part of primary teachers' training.
- Increase awareness that toys help in crossing language-barriers.

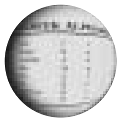
New scientific work must be done in order to give an overview of what kind of toys are useful for demonstrating physics. The functions of particular toys must be analysed. Everyone agreed with the statement that the use of a toy must be connected with an explanation afterwards. The depth of explanation is dependent on many factors, including the age of the audience and the phase of education. A toy is not only a toy, it has different functions in different parts of scientific education.

The participants wanted to communicate this message to others who use toys to illustrate physics: "Don't use toys without explaining them, behaving only like a magician. Use toys but please do not only play: A toy a day keeps boring physics away."

Everybody held the opinion that toys have a highly motivating function in learning processes. If toys were used in elementary education it could perhaps start earlier. Toys raise questions in children and students and make them active; they suggest investigations because a human being is a “homo ludens”, who –while playing– has become a “homo sapiens”.

For the convenience of the final presentation to the final session of Physics on Stage we agreed more or less about the following 15 statements, which express the spirit of the workshop:

- Toys are great starters
- Toys can introduce new concepts
- Toys that raise questions are the best
- Toys should suggest investigations
- Toys catch attention, provoke and stimulate discussion
- Toys cross language barriers
- Toys prove physics is everywhere around us
- Toys are essential to start physics in primary school
- Toys help understand technology
- Toys are cheap
- Toys are the champion motivators
- Toys give the feeling that anyone can do physics
- Toys strike an emotional string
- Toys make pupils feel the teacher is one of them
- Toys are not just for fun, they are for joy and joy lasts longer



At the end of the workshop we created the following letter written by a child who gives its wishes to Santa Claus:

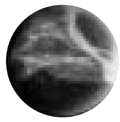
Dear Santa Claus,

I was a very obedient child. I never made my parents be cross with me, so please send me teachers

- who know that toys have a highly motivating function to raise questions and to suggest investigations,
- who are at one with us for playing with toys and make learning fun,

so please send me politicians

- who know that toys and scientific understanding should be part of primary teachers education
- who comprehend that toys will help crossing languages barriers.



I’m quite sure you can manage it because toys are not very expensive.

Yours sincerely, Harry Potter

Workshop Participants

Austria	Theodor Duenbostl, Johann Huber
Czech Republic	Vera Bdinkova
Finland	Heikki Kasurinen, Markku Sarimaa, Timo Suvanto
France	Vincent Coutellier, C Pinet, M Wafra
Germany	Joachim Brucherseifer, Klaus Buschhüter
Greece	Christos Ioannidis, Dionysios Karounias, Ioannis Kopanas
Hungary	Agota Lang, Zoltan Sebestyen
Ireland	Cathal Flynn, Angela Kelly
Italy	Luciana Ceccacci, Ivana Cocco, Alen Janni, Valentina Montel
Netherlands	Hubert Biezeveld, Louis Mathot
Norway	Harld Kolderup, Einar Oterhom
Poland	Teresa Calka, Jan Tokar
Slovak Republic	Martin Makuch
Spain	Adolf Cortel, Alejandro del Mazo, Rafael Garcia Molina
Sweden	Lars Ake Holmgren, Olle Östklint
United Kingdom	Jim Jardine

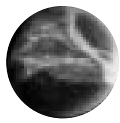
Workshop 9: The Place of the Internet in Physics Education

Leader: Robert Cailliau (CERN)
Rapporteur: Jose Sanchez Troncoso (European Space Agency)

Summary
In the last ten years, the development and rapid growth of the so-called Information Society has changed the way in which many of us live our daily lives.
New tools are touching all the spheres of our activity, and education has been one of the most important goals from the beginning.
The power of the internet as a tool is not in doubt, but this is not enough: we have the tool, but we must learn how to use it for education. This is one of the biggest challenges for internet-related education projects: how to use the Internet, how to organise the vast amount of data available, how to coordinate all the different groups that are working towards the same goals but in different places, etc...
During this workshop some of those problems were discussed, and we had the opportunity to discover how different countries face them. The lack of an organisation to coordinate the efforts of separate groups seemed to be the main problem, as well as who could support and finance such an organisation.
It was clear in the end that coordination, cooperation and sharing of experiences are the fundamental initial steps to introduce the Internet into physics education.

Recommendations

- Join the European School Net: it federates other nets.
- Guarantee financing and future website existence.
- Do quality research, by and with teachers at schools, on the learning process in internet-based teaching.
- Research, develop and evaluate different methods of using internet resources.
- Bring internet-based teaching into professional development programmes in each country.



Workshop Participants

Bulgaria	Veselka Radeva
Czech Republic	Jitka Houfkova
France	Monique Schwob
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Hungary	Beata Jarosievitz
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Norway	Vegard Engstrom
Slovak Republic	Jozef Demko
Spain	Angel Franco, Jose Gonzales-Lopez, Pedro Padro
Sweden	Anders Vaesterburg
Switzerland	Fritz Gassmann, Heini Mühry
United Kingdom	Denise Gault
CERN	Robert Cailliau
ESA	Jose Sanchez Troncoso

Workshop 10: New Tools in the Classroom

Leader: David Hammond (United Kingdom) & Richard Nixon (United Kingdom)
Rapporteur: Joyce Van Dam (European Space Agency)

Physics is exciting not only to physicists but also to young people. We must continue to find ways to excite and motivate young people to explore and enjoy the beauty of our subject. New technology can provide opportunities to do this. For example, new technologies enable the sharing of ideas and information between more people than ever before.

The variation in the use of new tools in Physics education reflects the differences that exist in society as a whole. It is clear from members of the workshop that there are great differences between the provision of new technologies and the associated training needed to use them effectively in the countries represented. If physics education is to help prepare young people for our ever-changing technological society it must involve new technologies in its delivery. This must only be done in such a way as to add value and enhance learning. If this is to be done it will involve training for all physics educators to provide the opportunity for all young people to experience the use of new technologies.

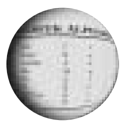
It is clear that if the use of new technology within teaching is to be effective then it must enhance and add value to that which already exists.

Using new technology in an inappropriate context or approach may be a barrier to learning. Therefore when to use new technology and how to use it must form an integral part of any training. Teachers must ask themselves when using new tools in their teaching, why, when and where they are appropriate.

Recommendations

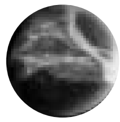
- Funding agencies must recognize the financial implications of introducing and maintaining information and communication technology (ICT) in schools
- Training must be financially supported so that teachers are aware of the pedagogical implications of using ICT in physics education.
- There is a need for the development of a central database to enable the exchange of information on the use of ICT in physics education.
- Physics teaching should reflect society in using ICT, where appropriate, to add value to and extend the learning experience.
- Partnerships should be developed between schools, higher education and industry to enable pupils to access and experience the use of new technologies.
- Producers of new technologies for education should be encouraged to see compatibility in new and updated features as a development priority.

Why - Information and communication technology (ICT) can help pupils learn by
- Enhancing enquiry skills
- Providing access to sources
- Developing understanding
- Providing access to perspectives
- Contributing to pupils' awareness of ICT in society



Where - ICT adds value through
- Extension of work
- Enhancement of the learning experience
- Avoiding repetition of tedious tasks
- Displaying data
- Enabling interpretation of data

When - by evaluating its use
- Ensuring its use is non-trivial and enhances learning
- Its use provides the most effective means of achieving the learning objectives
- Ensuring efficient use of time
- Providing opportunities for evaluation and reflection



Following lengthy discussions during the workshop sessions, the following areas have been identified as being crucial to ensure the successful implementation of the use of new tools in physics education. This workshop therefore makes recommendations in the following areas -

- Funding of new technologies
- Training of teachers in new tools
- Development of a central European database
- Reflection of new technologies in society within physics Education
- Development of partnerships between schools, higher education and industry
- Compatibility of technologies

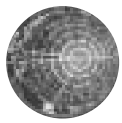
Funding
Funding agencies must recognise the financial implications of introducing and maintaining ICT in schools.
It is not sufficient to simply provide funding for the initial purchase of hardware unless provision is made for the ongoing maintenance of the equipment and the training of all teachers in its use.

Training
Training must be financially supported so that teachers are aware of the pedagogical implications of using ICT in physics education.
It is clear that the levels of expertise in the use of new technology in physics education varies both between and within countries. If the education in physics for all young people is to reflect the increasing use of technology in society we will have to implement a training programme which involves all physics educators.

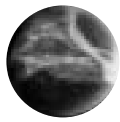
This training will provide a learning experience for educators, which must provide them with the confidence and expertise to use the technology. It must include, as an integral part of this training, the pedagogical aspects of using new technology in physics education.

Database
There is a need for the development of a central database to enable the exchange of information on the use of ICT in physics education.
It is clear that what is new technology for some is old technology for others. There exists a wide variation in the use of new technology in teaching. To facilitate the effective spread of good practice in its use it is felt that there would be great advantages in the creation of a central resource for physics educators. This contributory database would facilitate the sharing of good practice for all educators across Europe. It would enable educators to contribute to and research from a resource, which could identify projects, initiatives and good practice in the use of new technology within Europe.

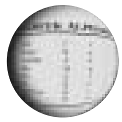
Reflect society
Physics teaching should reflect society in using ICT, where appropriate, to add value to and extend the learning experience.
Teachers should be able to identify the appropriate use of ICT by evaluation of the use of new technologies. Inappropriate use of new technologies can be as damaging as appropriate use can be enhancing.

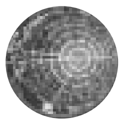


Partnerships
Partnerships should be developed between schools, higher education and industry to enable pupils to access and experience the use of new technologies.
Higher Education institutions, centres of excellence and industry have a role to play in providing access to new technologies for schools. This could be provided in several ways. They may provide remote access through the internet to equipment and technologies, which are not available in schools, e.g. carrying out complex experiments which cannot be done in schools. Alternatively by opening up laboratories which have new technological instruments they could provide opportunities for pupils to have hands on experience with the latest up to date technologies.



Compatibility
Producers of new technologies for education should be encouraged to see compatibility in new and updated features as a development priority.
Schools are often forced to abandon relatively new equipment, as it becomes obsolete due to the rapid development of new technologies. Producers should ensure that new versions of technology is, where possible, compatible with that of older equipment and of other producers.





Workshop Participants

Austria	Klaus Albrecht, Christian Gottfried, Leopold Mathelitsch
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Greece	Konstantinos Kampouris, Filippos Plattakis
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Portugal	João Antunes, André Baptista, Ângela Costa, Márcia Novais
Sweden	Jonas Enger, Christer Nilsson, Anna-Eva Olsson, Samuel Sollerman
United Kingdom	Richard Hammond, David Nixon
ESA	Joyce Van Dam

Workshop 11: ESO, ESA, CERN and the EU

Leader: Claus Madsen (European Southern Observatory) & Clovis de Matos (European Space Agency)
Rapporteur: Detlef Kaack (Germany)

This workshop was asked to consider the following issues:

- What contribution could/should such organisations make to physics education?
- At what levels should contributions be made?
- What proposals are there for the long term?
- Is there a role for such agencies in a European network?

Already, the European science organisations have arranged a number of activities to stimulate scientific awareness and interest in the natural sciences. These include school visits, open days, permanent and travelling exhibitions and student competitions. For statutory, financial and practical reasons these activities have remained at a modest level. Nevertheless, with these activities important experience has been gained, upon which more coherent programmes may be developed.

Recommendations

- Education is a key priority for Europe and European science organisations and the EC must be involved in its development.
- Education and outreach should be integrated with research projects using a 1% share of their budget.
- The EC, the European physics organisations (POs) and endorsed teacher networks and national organisations should promote both short and long term activities.
- POs should have teachers-in-residence to allow in-service training and outreach activities, supported by EC programmes.
- POs should communicate state-of-the-art science in the EU languages and should celebrate European achievement.
- Extracts from PO databases should be tailored for educational use.

1. Education – A Key Priority for Europe

Education should be seen as a key priority for Europe. The European science organisations and the European Commission can – and should – make a contribution towards this.
With their particular expertise, the intergovernmental science organisations can make a unique contribution towards science education. In conducting front-line research, these organisations 'produce' new knowledge which should be made available to students and to the public at large. However, in order to promote the progress of European science, and to make European careers in science attractive to young people, the educational efforts of the European science organisations should not only focus on communicating state-of-the-art science but also further the recognition of European achievements in science. In addition, the European science organisations are building up enormous databases, extracts of which could be used for educational purposes.

2. Disseminating the knowledge

We are aware of the existence of efforts by individuals and groups devoted to the dissemination of scientific information at the national level. Therefore it is important to use the existing structures to the largest possible extent. In this sense, the educational activities of the international organisations should enrich and complement these efforts. A close co-ordination between the European and the national organisations in this field is therefore important.

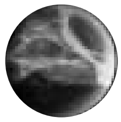
3. Helping teachers

3.1 Learning material for students and background information for teachers

In the context of a wide-ranging collaboration between scientific institutes and the educational community, the European science organisations should provide up-to-date information and teaching materials to schools and universities. To this end, the collaboration of the European science organisations and the teaching community may be facilitated by having teachers in residence at the European science organisations. The teachers can use their considerable professional experience to help transform the complex scientific information into useful teaching material. Furthermore, it is important that teaching materials and other information are available in the languages of the member states.

3.2 Special educational outreach programmes

The European science organisations should identify, promote and jointly co-ordinate long-term educational activities. Furthermore, short-term activities, such as those carried out within the European Science and Technology Week, offer attractive possibilities to stimulate the interest in science amongst young people.



However, it was strongly felt that the lead-times for such pan-European educational activities were too short. Giving educational institutions more time to prepare should achieve better responses.

Also, the European science organisations should provide the possibilities of increased, direct interaction between students and scientists working within these organisations. This may include periodic webcasting and similar events.

3.3 In-service training possibilities

Bringing teachers up-to-date with the development of front-line research is a precondition, both for offering modern education and for attracting the interest of pupils and students. Offering of training courses for teachers at the European science organisations is a possibility that should be pursued. These training courses should be connected to or tied into existing or future EU funding programmes.

Within the context of in-service teacher training by the European science organisations the possibility of offering recognised certificates to teachers should be explored.

3.4 Teachers' Networks

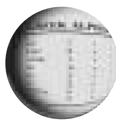
Teachers' Networks form an important interface between the European organisations, related national organisations and the school systems of the member states. Often, however, these networks are highly dependent on the work of a limited number of enthusiastic teachers working in relative isolation with little or no supportive infrastructure. Formal endorsement by the European science organisations may improve the efficiency of these networks, by enabling them to enlist national support and gain access to existing infrastructure.

4. Funding

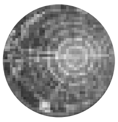
It is recommended that 1% of the budgets for research projects be devoted to related public communication and educational activities.

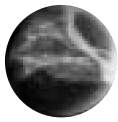
These funds should enable individual research projects to integrate their outreach and educational programmes with the production and use of project-specific materials.

This funding should be complemented with support programmes sponsored by the European Commission. These programmes should be tailored to specific needs, in



particular with respect to travel and subsistence in connection with the Teachers-in-Residence proposal, in-service training of teachers at the European Science Organisations and activities within the European Science and Technology Week. In particular the 6th Framework Programme and possibly other EC programmes for teaching should be developed with a view to facilitating such possibilities.





Workshop Participants

Belgium	Rita van Peteghem
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Czech Republic	Jiri Rames
Finland	Antero Hietamäki
Germany	Detlef Kaack, Volker Martini, Peter Stinner
Italy	Vincenzo de Chiara, Frederica Guadagnini, Fabio Mantovani
Norway	Knut Jørgen Rød Odegaard
Poland	Wojciech Nawrocik
Portugal	Mario Jorge Oliveira, Liliana Novais, Diego Oliverira a Silva,
Spain	Lourdes de Pedraza Velasco
Sweden	Björn Lingons
United Kingdom	Andrew Morrison, Margaret Penston, Alan Pickwick
CERN	Antonella Del Rosso, Mick Draper, Riitta Rinta-Filppula, Michelangelo Mangano
ESO	Claus Madsen
ESA	Clovis de Matos
EC	Stephen Parker

Workshop 12: Focus on Teachers

Leader: Rosa Maria Ros (Spain) & Brenda Jennison (United Kingdom)
Rapporteur: Steven Chapman (United Kingdom)

Introduction
The group looked at the factors affecting the recruitment of teachers and how these can be changed to improve the crisis facing physics teaching. In some countries there is a critical shortage of physics teachers and a lack of real quality in the ones that are recruited. In other countries the situation is not yet critical, but the failure to reach recruitment targets is recognised in all of the countries we discussed.

There is more detailed information about the situation in the countries represented by the group in an appendix, available on request.

Our Recommendations

- Teachers' conditions of service need to be improved (working hours, preparation time, technical help, support, training and professional development, promotion prospects).

There are increasing demands on the time of teachers throughout Europe. Teachers spend at least as much time preparing, marking and carrying out administrative tasks as they do in front of students. Some teachers have little or no technical support for their lessons; in-service training is patchy and incoherent and promotion for a teacher often means leaving the classroom for a management role.
There is an increasing emphasis on the accountability of the teacher, reinforced by inspection, rather than advice to encourage improvement.

- Other professionals often have higher salaries and pensions than teachers. This needs to be rectified: teachers' salaries and pensions should be brought in line with those of other professionals with comparable qualifications.

There are a whole host of lucrative opportunities for Physics graduates and teaching must compete with these. Teachers' low pay has a significant demotivating effect on those in the profession and is not attractive to potential recruits outside it. New graduates carry large debts from their previous studies; mature applicants may have considerable family responsibilities. In some countries the average age of trainee teachers is rising. Training does not follow directly after graduation. The Bologna Agreement is affecting the structure of teacher training in some countries.

Recommendations

- Teachers' conditions of service need to be improved (working hours, preparation time, technical help, support, training and professional development, promotion prospects).
- Teachers' salaries and pensions should be brought in line with those of other professionals with comparable qualifications.
- Teachers need a good training before, and further professional development during, their careers. Teachers, like other professionals, need regular paid leave in order to improve their knowledge and skills.
- We recommend the promotion of personal contact between ordinary classroom teachers in different European countries in order to exchange and share teaching ideas.
- We recommend that, because of the growing crisis, an audit of the quality, quantity and competences of teachers throughout Europe be carried out.
- In most countries, respect for teachers by pupils, parents, governments and society is falling - this can and should be improved with more positive and active support for teachers.

- Teachers need good training before, and further professional development during, their careers. Teachers, like other professionals, need regular paid leave in order to improve their knowledge and skills.

A professional science teaching institute is needed in each country to develop and disseminate material for use in teaching. In addition, some form of integration on a European level is also needed to co-ordinate the work of different countries. This work should be produced in each of the languages of the EU and due notice taken of the teaching culture of each country. Research into pedagogy must also fall under the remits of these institutes so that research can receive a courteous translation for teachers to apply in schools.

- We recommend the promotion of personal contact between ordinary classroom teachers in different European countries in order to exchange and share teaching ideas.

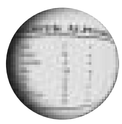
Time is needed to develop the ideas which have been discussed at Physics on Stage. This conference should be the beginning of the process not the end. How will the national organisations take forward the work done here this week? It is extremely difficult for ordinary teachers to get away from their classes to interact in person with their colleagues from other countries: payment for supply teachers is a real problem. New technology is important in following face-to-face meetings, but should not be a substitute for them. No country has a monopoly on good ideas and there is much to be learnt from sharing, exchanging and disseminating good practice.

- We recommend that, because of the growing crisis, an audit of the quality, quantity and competences of teachers throughout Europe be carried out.

Governments should be able to produce all the data concerning education. An analysis of information including student and teacher populations, details of schools and other educational institutions, age profile of the teaching community and so on is essential. This information needs to be gathered as quickly as possible. Research into why we are not getting teachers entering the profession is also needed quickly before it is too late. There is some anecdotal evidence of low teacher recruitment, but it must be backed up with detailed quantitative data, such as: information about work-loads; what sort of subjects teachers teach besides physics; whether integrated, combined, separate, or co-ordinated science is taught. There should be a central collection of education research data and a means to disseminate the materials to teachers. Material should respect and account for structural, educational and cultural differences between the diverse regions of Europe.

- In most countries, respect for teachers by pupils, parents, governments and society is falling - this can and should be improved with more positive and active support for teachers.

The status of teachers has fallen to a very low level in some countries. This has had a significant effect on recruitment. Potential teachers hear horror stories about violent incidents in classrooms, high work loads, poor working environments, as well as a lack of respect for teachers in general.



Workshop Participants

Belgium	Marc Beddegenoodts
Bulgaria	Snejana Pavlova
Czech Republic	Leos Dvorak, Josef Trna
Germany	Werner Warland
Ireland	Paddy Healy
Italy	Christina Palici di Suni
Netherlands	Dick Hoekzema
Poland	Adam Smolski
Spain	Maria Jesus del Arco, Rosa M Ros
United Kingdom	Steven Chapman, Brenda Jennison

Workshop 13: Curriculum Development

Leader: Fernand Wagner (European Associatio for Astronomy Education)
Rapporteur: Wolfgang Welz (Germany)

It seems meaningful to close the series of workshops with the issue of the curriculum, because the curriculum should give the answers to the questions and offer solutions to the problems which teaching and studying raise and which have been mentioned and discussed intensively during this exciting European meeting. However, curriculum development itself is suffering its own crisis

> *"The term 'curriculum' encompasses the content, structure and process of teaching and learning, which the school provides in accordance with its educational objectives and values.*
> *The curriculum in schools is concerned, not only with the subjects taught, but also with how and why they are taught and with the outcomes of this activity for the learner.*
> *The proper management of this curriculum should be such as to provide students with a range of understanding, knowledge, skills and attitudes best suited to their personal development, and to enable them to make a productive contribution to the society in which they live."*

This quotation of a "Brief description of the Irish Educational System" [Dublin, August 1999], mentioned by the chairman of the workshop as an opening statement shows clearly that 'curriculum' is a terribly broad concept. This fact implies that it is absolutely hopeless to give fair descriptions of the peculiarities of every single country, let alone give a detailed account of all points of similarity or difference.

The first two of three workshop sessions served the purpose to gain access to the variety of problems in teaching physics in the European countries and to get some idea of the state of curriculum developments. Brief descriptions of basic insights - prepared and presented by Silvia Pugliese Jona (Italy), Wolfgang Welz (Germany) and Stuart Naylor (UK) – led from three different points of view into a deep, serious and profound discussion.

While on the one hand the problems seemed to be very similar in all countries, on the other hand different approaches can be found to solve them, even within one country (e.g. in Germany 16 curricula are practised in parallel). Furthermore, some countries are in the process of constructing new curricula (e.g. Belgium and Italy); in principle they have the need and the opportunity to reassess questions and matters of education more deeply than those who are only willing to evaluate and correct their existing traditional and highly integrated concepts.

Recommendations

- There is a need for curricula that clearly indicate: the content, the contexts, teaching methods, the degree of flexibility and the expected outcomes.
- The process of development of a curriculum should include the steps : innovation, participation, realisation, evaluation.
- A curriculum should enable continuous development and the government should enable the realisation of the curriculum.
- There is no need for a single European curriculum, but there is a necessity to discuss the variety of solutions.

With respect to the complexity of the situation, the workshop concentrated on a number of issues that seem to be central to physics teaching in all countries and may contribute to cross-national inspiration. To say it in a more strict sense: a common list of essential requirements on a national curriculum should be formulated in order to give the national delegates concise "European" support for their hard work, when they discuss within the political field their proposals of alleviating measures to the current state of widespread physics illiteracy among Europe's citizens.

The following questions structured the wide-ranging discussion within the workshop sessions. The account is given to outline the whole host of aspects:

– What is the purpose of the curriculum?
– Should the curriculum aim at science for all or for the specialists?
– How much autonomy should be allowed for the teacher, and how much for the student?
– Should the curriculum contain only the contents or should it describe the contexts?
– How should the curriculum deal with methods and outcomes?
– What is the connection between assessment (examination) and curriculum?
– How can continuity be guaranteed in the progress of education?
– How should a new curriculum be developed?
– How does innovation enter into curricula?
– How should the constraints be addressed?

The ideas, answers and proposals to these questions were summarised into six main theses for presentation in the conference closing session. The comments attached may illuminate the context of the discussions and the intention of the statements.

Thesis 1: A great variety of curricula exist (especially in the mind of teachers).
As is the case with other issues, the philosophy as well as the practice differ very much from country to country. Three levels of curricula (intended, implemented and attained) are found within Europe.

Normally “curriculum” is interpreted as the “curriculum documentation” which describes the desired and expected experiences for teachers and students following that curriculum. We cannot define the curriculum actually experienced by every individual student.

We have to keep in mind that there exists in the mind of every teacher an individual curriculum which might be more effective than the official one. It leads us to a very important restraint to the success of evaluation or changing things when we remember a basic insight: any teaching system cannot rise above the average level of its teachers.

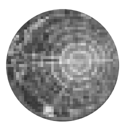
Thesis 2: All curricula seem to have to deal with similar problems.
Firstly, for example, principal aspects of the results of the TIMS-Studies show that: many pupils are able to execute technical algorithms well but they can hardly use technical algorithms in other contexts; they are seldom able to translate everyday life questions into technical questions; and they are not able to solve more complex questions independently. Too many of them forget fast and give up relatively fast. Preconceptions and misconceptions are almost unchanged by science lessons!

Physics is classified by the majority of pupils as an extremely important subject. Despite this opinion, the predominant number of pupils do not think themselves to be competent enough to learn the contents of this subject. This effect is stronger with girls than with boys.

Secondly, the current state of widespread physics illiteracy among European citizens must be mentioned again. Thirdly, lack of money is felt to be one of the main constraints.

Thesis 3: There is a need for curricula that indicate clearly the :

, content
, contexts
, teaching methods
, degree of flexibility
, expected outcomes.



The general requirement of a national curriculum to set a framework for the actions that must be taken within the school system in order to ensure an adequate education for young people seems not to be questionable. Contents have to be described. A question of increasing interest is how to put contents into contexts that the students will respond to, in order to overcome the gap between physics and everyday life. A balance should be found between “general issue” contexts (traffic, communication, etc..) and “applications” contexts (lasers, microelectronics, etc.) with respect to the age of the pupils and the different kinds of schools.

There is a need to describe methods of teaching and learning. The success of teaching strongly depends on the repertoire of methods handled by the teacher. And the success of the learner depends on the way they are engaged in activities. Practical work is so close to the heart of physics teaching that it should deserve – and get – its own section.

The curriculum must describe, but not prescribe in a strong way. If the teacher is subjected to firm discipline within contents, contexts and methods this will prevent the inclusion of new applications and others which may be of more relevance to the students as time progresses, i.e. there must be room for acceptance of the curriculum by the teacher and room for innovation.

The intended outcomes must also be clearly described. Teachers and students should know the desired or intended outcomes in understanding the world and be properly prepared for the appropriate assessment.

Thesis 4: The process of development of a curriculum should include the steps :

- innovation
- participation
- realisation
- evaluation.

The key point for success is participation. Teachers must be involved in the development and be consulted to feel that they have ownership of the curriculum and its development. If the curriculum is imposed from the top (i.e. by the government) it is less likely to be implemented with any enthusiasm by the teachers. Also, without teacher input, the curriculum changes might not appreciate the constraints under which teachers have to work.

Thesis 5: A curriculum should enable continuous development and the government should enable the realisation of the curriculum.
To allow for innovation, there needs to be a debate amongst the physics teaching profession about what and how physics should be taught. This debate should include experiences within the European countries. Through this debate, new ideas and examples of best practise will spread and become incorporated in the curriculum by those in charge of its development.

Once the curriculum has been agreed upon, all constraints must be addressed to ensure its full implementation.

Lack of money is thought to be the main constraint. It results in problems regarding:
– good pay and conditions to attract the best people into teaching,
– good laboratory accommodation and
– good teacher-training in methods (pedagogy), new apparatus or information technology as well as in modern physics.

Pilot projects should be set up and research should also be done to identify the benefits that are possible when the constraints are overcome. Nevertheless the government has to ensure an effective and successful implementation of the curriculum.

Thesis 6: There is no need for a single European curriculum, but there is a necessity to discuss the variety of solutions.
This is the main message of the workshop to all of those who feel responsible for this great and exciting European conference. Physics is a rapidly developing method of understanding our world and there is a necessity to provide a continuous supra-national exchange of ideas and proposals of local or national solutions for the crisis of physics education. This conference can only be the starting point of an ongoing debate on the future development of physics education in Europe.

Workshop Participants

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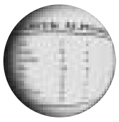
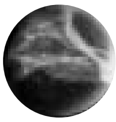
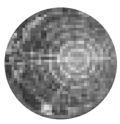
Germany	Berthold Freytag, Michael Kobel, Gerd Riedl, Gerhard Sauer, Wolfgang Welz
Italy	Silvia Pugliese Jona
Luxembourg	Fernand Wagner
Netherlands	Paul Verhagen
United Kingdom	Stuart Farmer, Stuart Naylor, Elisabeth Swinbank, Mary Whitehouse







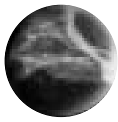
List of recommendations from the workshops

Workshop No. 1 - Mapping the Crisis

- Introduce a reward system for teacher training schemes, supported by industry and the scientific community, which highlights teaching skills
- Organise a lobby to boost the image of physics and which would ensure that lack of money is not adversely affecting schools.
- Introduce physics into the mainstream (e.g. television, role models) to increase awareness of the connection between physics and daily life.
- Increase political awareness of the problems raised at Physics on Stage.
- Make physics lessons more fun and less mathematical for the majority of students
- Increase awareness that people trained in physics are very employable, in many areas of society.

Workshop No. 2 – Physics in Primary Education

- All children in the European Union should have access to science experiences from the earliest age, that is, at home and from kindergarten to the age of 12 and onwards.
- All teachers of young children should have access to professional development in science education.
- The EC should set up a 'Virtual Resource Centre' based around an internet site.
- A European Association for Young Scientists should be created to provide opportunities for children to engage in informal science activities at home and in school.
- All European Research Centres should have an Education Division.



Workshop No. 3A – Physics in Secondary Education

- Learning should be based on everyday life in contexts highlighting physics, past, present and future.
- Students' learning should incorporate experimental, theoretical, mathematical and Information and Communication Technology (ICT) skills.
- A range of teaching methods must be used to enable students to become independent learners.
- To provide appropriate learning environments, teachers' skills need regular up-dating.
- Government criteria for physics teaching should provide enough flexibility in course design to allow context-based teaching.
- Adequate equipment, sufficient teacher training and the promotion of physics must be financed.

Workshop No. 3B – Physics in Secondary Education

- It should be recognised that physics is absolutely necessary to everybody, because it is a part of today's culture.
- Physics teaching must develop a way of thinking for the majority of the students, who will never become scientists.
- Physics teaching should provide meaningful explanations to students all over the world, so it must be linked to reality.
- Physics teaching should be tuned to different school levels and different interest groups.

- As physics is an experimental science, teaching requires adequate human and material resources, reasonable class sizes and adapted schedules to develop different aspects of scientific methods.
- Teachers of physics require skills in physics, didactics, pedagogy and an open minded attitude. Thus, teacher training in accordance with those objectives is essential.

Workshop No. 4 – Physics and Public Understanding

- Universities, research centres, science industries and physical science organisations should:
- Collaborate to provide courses in science communication for journalists, policy makers, scientists, science students, etc.
- Bring physics to the people through the establishment of community-based science centres and outreach programmes.
- Sell physics to the media by making it accessible and relevant to the public and through linking physics to other disciplines.
- Look for effective ways to respond to people's needs and interests.
- Value and expect the communication of scientific research.

And finally:
- All the participants of this workshop realise the importance of teaching science in general, and physics in particular, to everybody, and therefore each of us will try to do at least one thing to communicate physics to public and will report on it at the second "Physics on Stage" festival.

Workshop No.5 – The Role of History & Philosophy in Physics Education

- History and philosophy of science should be part of the training of physics teachers.
- Information about successful and unsuccessful uses of the history of science in teaching should be collected and made widely available.
- Historical and physical societies should be encouraged to collaborate.
- Through the history and philosophy of science, a more realistic image of science should be given. Tools should be developed to address social issues involving science.
- The history and philosophy of science should be used to clarify the relationship between the scientific world view and those from other fields of knowledge.

Workshop No. 6 – Consideration of the Major Issues of Today

- It should be recognised that physics has immediate relevance in understanding and solving problems of sustainable development and growth.
- A curriculum should address the above issues and the immediate impact of physics on everyday life, based on a complex, interdisciplinary approach.
- The pace of research and the increasing availability of information calls for relevant and on-going teacher training.
- International cooperation should form an integral part of the development of curricula at local and national levels.
- Students and teachers should be given reliable information from a variety of sources, which is up-to-date and free from propaganda.
- Curricula should enable students to take reasoned decisions, weighing up evidence and risk in a social and economic context.

Workshop No. 7 – Women and Physics

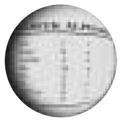
- Gender awareness should be included in the education of teachers. Physics lessons should include physics that girls will like.
- Gender awareness is needed at higher levels in academia.

- Women with small children should be supported by academic institutions through the provision of childcare, job-sharing, part-time jobs, etc.

And some more radical suggestions:
- Let girls start school one year earlier than boys.
- If measures to attract girls to physics fail, then teach them separately from boys.

Workshop No. 8 – Physics and Toys

- Make teachers aware that toys have a high motivating function: they provoke questions and lead naturally to investigations.
- Encourage teachers to join children in playing with toys and make learning fun.
- Toys and scientific understanding should be part of primary teachers' training.
- Increase awareness that toys help in crossing language-barriers.



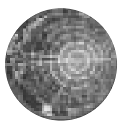
Workshop No. 9 – The Place of the Internet in Physics Education
- Join the European School Net: it federates other nets.
- Guarantee financing and future website existence .
- Do quality research, by and with teachers at schools, on the learning process in internet-based teaching.
- Research, develop and evaluate different methods of using internet resources.
- Bring internet-based teaching into professional development programmes in each country.

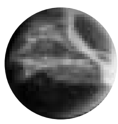
Workshop No. 10 – New Tools in the Classroom

- Funding agencies must recognize the financial implications of introducing and maintaining information and communication technology (ICT) in schools.
- Training must be financially supported so that teachers are aware of the pedagogical implications of using ICT in physics education.
- There is a need for the development of a central database to enable the exchange of information on the use of ICT in physics education.
- Physics teaching should reflect society in using ICT, where appropriate, to add value to and extend the learning experience.
- Partnerships should be developed between schools, higher education and industry to enable pupils to access and experience the use of new technologies.
- Producers of new technologies for education should be encouraged to see compatibility in new and updated features as a development priority.

Workshop No. 11 – ESO, CERN, ESA, and EU

- Education is a key priority for Europe and European science organisations and the EC must be involved in its development.
- Education and outreach should be integrated with research projects using a 1% share of their budget.
- The EC, the European physics organisations (POs) and endorsed teacher networks and national organisations should promote both short and long term activities.
- POs should have teachers-in-residence to allow in-service training and outreach activities, supported by EC programmes.
- POs should communicate state-of-the-art science in the EU languages and should celebrate European achievement.
- Extracts from PO databases should be tailored for educational use.





Workshop No. 12 – Focus on Teachers

- Teachers' conditions of service need to be improved (working hours, preparation time, technical help, support, training and professional development, promotion prospects).
- Teachers' salaries and pensions should be brought in line with those of other professionals with comparable qualifications.
- Teachers need a good training before, and further professional development during, their careers. Teachers, like other professionals, need regular paid leave in order to improve their knowledge and skills.
- We recommend the promotion of personal contact between ordinary classroom teachers in different European countries in order to exchange and share teaching ideas.
- We recommend that, because of the growing crisis, an audit of the quality, quantity and competences of teachers throughout Europe be carried out.
- In most countries, respect for teachers by pupils, parents, governments and society is falling - this can and should be improved with more positive and active support for teachers.

Workshop No. 13 – Curriculum Developments

- There is a need for curricula that clearly indicate: the content, the contexts, teaching methods, the degree of flexibility and the expected outcomes.
- The process of development of a curriculum should include the steps : innovation, participation, realisation, evaluation.
- A curriculum should enable continuous development and the government should enable the realisation of the curriculum.
- There is no need for a single European curriculum, but there is a necessity to discuss the variety of solutions.

Concluding remarks to “Physics On Stage”,

Richard West (ESO)

on behalf of the International Steering Committee (ISC)

Advances in the basic sciences foster progress in technology and vice-versa. Since some time, we find ourselves in a world that would no longer function properly, indeed could no longer guarantee us the quality of life to which we are used to, without the continuous application of that technology. But while our dependence on advanced technology has grown, most people’s ability to comprehend it has not followed step. Public scientific literacy in Europe is not keeping up and there is a real risk of associated, deep problems. To mention a few: the inability of the individual to make well-founded decisions that demand a minimum of technical insight, the progressive dependence on foreign products, exacerbated by a future lack of local specialists to innovate, perhaps even to maintain existing technology.

The “Physics On Stage” final event at CERN in November 2000 provided a most important opportunity to discuss this alarming state of affairs and the international participants did not fail to formulate a loud and clear message. As is clear from the preceding reports, the perceptions of some of the most pressing issues were sharpened and specific priorities were identified. The resulting overview of the current situation and the spelling-out of common goals in terms of improving physics literacy in Europe will contribute to the definition of the future strategies. The well-founded recommendations from this distinguished audience that are expounded in the present document will surely be heard by the policy-setting national and international authorities.

This event represented the high point of the European Union’s Science and Technology Week 2000. There is little doubt that it lived up to the expectations by the participants, if not surpassed them. It was a most unusual meeting in several respects:

- It brought together a large spectrum of highly qualified people, not just the recognised experts, but also many from the grass-root level;
- The participation was most representative, in terms of geographical coverage and educational background, and with particular emphasis on physics teachers. The conclusions, as recorded in the present document, are therefore uniquely representative in the same terms and hereby gain much weight;
- The participants came well prepared through the national selection process, but in view of the experimental character of the meeting, not quite aware of what they should expect. Moreover, the meeting attempted to cover a broad spectrum of issues in relatively short time. For this reason, much of the joint response is the outcome of spontaneous and greatly stimulating discussions, and the formulated recommendations of high quality and impact;
- Based on information from the many nationalities represented at the meeting, some of the worrying premises for the meeting were fully and quantitatively confirmed. There is indeed a widespread and general lack of physics literacy of the European public; a dramatic demographic situation among secondary physics teachers is rapidly developing - many will soon reach the age of retirement and the current recruitment rate of young teachers is alarmingly low.

But what is it then that makes physics less attractive? Why this widespread public attitude of blissful ignorance? Why do gifted, young people hesitate to enter into the world of physics? Those are some of the key questions for which the meeting attempted to formulate answers.

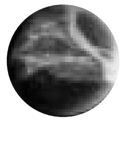
The focus was on the sector of school education, in particular on the secondary level. Thus, many of the participants were active physics teachers with much practical experience and knowledge of the particular strengths and weaknesses of physics education at this level in their respective countries. The emphasis on this sector was established by the International Steering Committee from the outset, in consideration of specific factors:

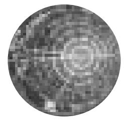
- The teachers are central to the education of young people and are highly influential in the resulting perceptions about physics by the citizens. This is particularly true for those who receive no higher education and have no or only loose professional links to this and related sciences;
- Only well qualified, highly motivated teachers can properly convey the subject to their pupils and achieve a lasting impact on the general attitude of their audience. On the contrary, teachers who are not well informed or lack inspiration can easily destroy any prior affinity to the subject;
- Unless teachers receive in-term training, they quickly lose contact with the real state of the subject, especially in those scientific and technological fields that move rapidly forward.

The meeting came up with a broad bouquet of weighty recommendations, some of which are of particular significance:

- YES, advanced and highly stimulating pedagogical methods and means for the teaching of physics at primary and secondary school levels do exist. However, the related knowledge and practical experience with their use is often vested in a small number of progressive teachers in a certain geographical area. Thus the opportunity to exchange such information at this meeting was extremely welcome to the participants. This greatly contributed, already during this event, to the dissemination of useful educational information all over Europe;
- NO, with some exceptions, the societal status of physics teachers does not match their societal importance. It is deeply disturbing to find how little some countries are willing to invest in the proper education of their young citizens. Consequently, it is becoming increasingly difficult to attract gifted young people to this profession, or to keep established educators motivated and effective. Unless urgent attention is paid to this fundamental problem by all related bodies, in particular the national governments and other decision makers, a true educational crisis will occur within the next decade;
- YES, Physics-On-Stage (2000) has proven the validity of its general concept, to show that physics can be effectively taught in new ways. A continuation, and preferably an institutionalisation of this programme is therefore highly desirable, in order to reach and activate a much broader sector of the educational community in Europe.

The special position and responsibility of the European Intergovernmental Research Organisations like CERN, ESA and ESO in this respect is evident. At the same time, the present problem is a very general one that cannot be tackled by the scientists and the educators alone – it demands the active collaboration and support of national governments and the European Union. In fact, a project like Physics On Stage that aims at alleviating the current lack of scientific literacy in Europe - be it by furthering the teachers conditions and providing them with access to the proper educational means and modern pedagogical methods, or be it in general public education - can only be successful if it is based on a long-term concerted effort and, it goes without saying, is also endowed with sufficient resources.





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