Fast knowledge expansion and rapid changes in society demand significant qualitative changes in the way physics is taught (Marx, 1980). Real implementation of new educational ideas in schools is possible only through adequate changes in teacher education. Physics as the most fundamental natural science forms the foundation of modern high technology and yet its image in society slowly but constantly deteriorates.

1) Significant qualitative changes are necessary

Society demands from educational system that the number of highly educated people permanently increases. It's a strategic issue. What is the position of physics and other natural sciences in it? Can physicists answer to those demands? Will the number of new physicists also increase along with the number of new lawyers and managers?

The basic problem of physics education lies in the fact that in many countries today high schools do not produce enough students who are interested in physics. There are therefore not enough good candidates who would like to major in physics or technical disciplines at universities. The reason is not physics itself, but the way physics is being presented at schools and how it is valued in society. The significant increase in the number of new physicists is therefore not likely unless some essential qualitative improvements occur in physics teaching - not only in strategic decisions, but also in implementation of those decisions.

The first step is to negotiate the real modernization of the teaching process in schools, according to the modern ideas that include constructivism, active role of students in the learning process, interactive teaching methods etc. as is suggested in many modern studies (see for example Bell & Gilbert, 1996). It was definitely shown (on smaller samples of students up to now) that such approach transforms physics from a frustrating, boring and incomprehensible school subject in almost the most interesting and easiest subject. Future teachers should be educated for that kind of teaching.

The experience shows that teachers who have already adopted the traditional lecturing routine hardly ever change their basic attitude toward teaching. The permanent in-service education of teachers is very important, but its main goal should not primarily be the content-oriented instruction of teachers, but the change in their attitudes toward teaching (Viennot, 2000).

Much better results can be achieved in pre-service teacher education, while student teachers have not yet adopted the traditional teaching routine. The experience shows that student-teachers accept with enthusiasm interactive teaching methods, which they use in physics education courses (didactics of physics), and during their student-teacher apprenticeship at schools. After graduation many of those students continue to use interactive methods in their teaching practice. The students of such teachers generally show much more interest in physics and appreciation for physics than students of traditional teachers.
2) The need for achieving some consensus on the structure of university physics programme

The current situation in different countries (while suggestions from Bologna Declaration are not yet implemented) is rather different. There are still some open problems on which there is no consensus in physics community. Here are some of these problems:

2.1 How to structure physics studies for prospective physics teachers?

Many models can be found among the models present at European universities. Two extreme models are:

Model A – Prospective teachers attend the same courses as prospective scientists and only differ in the last year of studies (fourth or fifth year, depending on the country), when prospective teachers choose didactics of physics and pedagogical courses.

Model B – Students choose to become teachers at the beginning of their studies and attend courses that are all designed specifically for them.

It can be said that model A has its roots in the second half of the 19th century (since 1870), when natural sciences became professionalized (Aikenhead, 1994), and separated from the society and technology, becoming thus self-sufficient. Until the process of socialization of natural sciences began in the middle of the 20th century slightly different versions of that model were in use in almost all European countries. Since then, more and more countries started to introduce model B of teacher education either alone or in parallel with model A. In Croatia, for example, change from model A to model B was introduced in 1974. However, it did not bring enough qualitative changes in the courses designed for prospective teachers. There is still too much emphasis on the mathematical formalism instead on the development of the concepts.

Here are some arguments in favour of the model B:

For quality teacher education students' personal motivation to enter teaching profession is very important. In model B, students decide at the beginning of the studies that they want to be teachers. In model A, many candidates possibly become teachers for different reasons. For example, in the course of the studies they start to feel inadequately competent to continue in scientific direction. Their choice of teaching profession is therefore the consequence of their failure in their first choice. It is not uncommon that such students are later not successful as teachers, because they lack motivation or communication skills.

Some physicists claim that “physics is physics”, and therefore both prospective physics teachers and prospective physicists need the same courses. That attitude does not take into account the fact that these two groups of students will need different skills in their future jobs. Prospective physicists will need more operational skills, often in a very narrow area, whereas prospective teachers need more insight in historical, philosophical and epistemological aspects of physical concepts, and ability to communicate these concepts to students who are at different stages of cognitive development. For instance, it would be desirable to include teaching about students' alternative conceptions, as well as real problem situations from the history of physics, already in general physics courses for prospective physics teachers.
2.2 Which combinations with other disciplines are desirable for prospective physics teachers?

In the majority of European countries the combination with the longest tradition is the combination of physics with mathematics. More recently combinations of physics with some other natural science have been introduced. In some countries, like Austria, it is possible to combine physics with any other school subject. In some cases both chosen subjects are treated equally and in other cases one is taken as the major subject and the other as the minor subject.

In Croatia, there are one-discipline studies for prospective physics teachers and interdisciplinary studies in the following combinations: mathematics and physics, physics and chemistry, physics and polytechnics with informatics, physics and informatics. The introduction of the combination of physics with any other school subject is being seriously considered in the light of Bologna process. That combination could bring far reaching positive effects. It would make physics studies for prospective teachers more attractive to candidates with a wide spectrum of interests and abilities. Many of them would like to combine physics with art, social sciences or some other humanistic discipline, which is impossible at the moment. The number of such students would certainly not be very large, but their influence on the image of physics and the process of its socialization could be significant and very positive.

2.3 How large is the relative fraction of physics, mathematics, pedagogical and didactics of physics courses in terms of their respective number of periods?

Although in most countries more or less the same basic physics and mathematics topics are studied, the total number of periods varies considerably. Even larger variations are found in the number of periods for pedagogical courses and didactics of physics. In Croatia, physics module in interdisciplinary combinations has 1320 periods. Of that number 240 periods belong to didactics of physics (lectures, seminars, laboratory work), and 60 periods to student teacher apprenticeship at schools. Since the size of the physics module varies considerably in different European countries it would be important that physicists from different countries achieve some consensus on how large that module should be.

Interdisciplinary studies are more difficult than one-discipline studies. The experience from Croatia shows that the number of students enrolled in interdisciplinary studies involving physics slowly diminished over the last 5 years while the number of students who study only physics significantly increased in the same period of time.

Student teacher apprenticeship at school is very important for the formation of the prospective teacher, but the quality of the teacher-mentor plays much more important role than the duration of the apprenticeship. According to our experience, it is better for students to experience constructivist teaching even for a short time than to spend long time with traditionally oriented teachers.

2.4 Pedagogical courses: Which is better, synchronous or successive model?

In the past, when prospective teachers were separating from prospective scientists in the last year of studies (model A from 2.1), the successive model, in which all pedagogical courses are placed in the last year of the studies, was the only possibility. Successive model
still has its proponents. From purely administrative point of view it is attractive, since it makes the organization of the studies simpler, but not necessarily better. Successive model is more and more being replaced by the synchronous model.

The advantage of the synchronous model is that it enables students to get continuous pedagogical education during their studies, but it can only be implemented if the whole studies are organized according to the model B. In Croatia, the synchronous model was introduced in 1974, and pedagogical courses are distributed over the first three years of the teacher studies in the following order: psychology of learning – 1st year, general pedagogy – 2nd year, general didactics – 3rd year. In this way these courses serve as an introduction to the physics education courses that are placed in the 4th year of studies.

3) Implementation of the suggestions from the Bologna Declaration

Since all discussions about the changes in teacher education in the last few years are led in the light of the Bologna Declaration from 1999, and meetings in Salamanca and Prague from 2001, it would be appropriate to consider their suggestions also when discussing general ideas about physics teacher education. In suggestions of the Bologna process for the higher education system, the pattern 3+2 is recommended. That pattern is already present in physics programmes for prospective physicists in some European countries (Klemperer, 2001), but is it applicable to physics studies for prospective physics teachers?

On the basis of discussions with colleagues from different countries a conclusion was reached that the model in which the first phase of higher education would last 3 years is not suitable for physics studies for prospective physics teachers. That is especially true for interdisciplinary studies where it would be even technically impossible to implement the 3+2 pattern. The basic problem is the competence of the students after 3 years of studies. Where could they teach? If they were allowed to teach even in elementary schools it would be a step back with respect to the present situation, and that is not desirable. This seems to be in conflict with the intentions of the Bologna declaration, which specifically mentions that Bachelor degrees should be relevant to the European labour market (Bologna Declaration, 1999).

Bologna declaration gives good suggestions for graduate studies. Physics teachers could get a 'Master of education' degree in 4+2 or 4+1 years. In the last 1 or 2 years of the studies the emphasis would be on students’ work on their Master thesis. What would happen with the structure of prospective physics teacher studies if the pattern 3+2 were imposed? People who think that this pattern can and should be implemented usually offer a simple administrative scheme: In the first 3 years of studies there are only courses with the contents of the studied discipline, while 4th and 5th year contain pedagogical and didactics of physics courses with some more content-oriented courses. That scheme looks simple, but contains some hidden dangers:

• After the finished first level (3 years) the candidates could not teach in schools, so no use is actually seen from the finality of the first level.

• The scheme directly implies the successive model for pedagogical courses and resurrects ideas about common studies for prospective physics teachers and prospective physicists in the first 3 years, which would both mean a step back compared to present situation.
The structure of physics programme is such that difficult contents of mathematics and physics are gradually introduced in the first two years, thus forming a foundation for the learning of theoretical physics and special areas of physics in the 3rd and 4th year. That programme cannot be squeezed into only 3 years because it would become too hard for students. Pedagogical courses that are distributed over the first 3 years offer a certain distraction from the difficult and abstract courses in physics and mathematics.

If the model 3+2 is accepted along with the fact that candidates cannot teach after 3 years of studies, but can after 5 years of studies, the overall effect would be that physics studies for prospective physics teachers have become a year longer than they are now and that would increase the probability of losing some candidates along the way.

As a conclusion it can be said that the preferred model for physics studies for prospective physics teachers would include model B for the structure of the studies, the possibility of combining physics studies with studies of any other discipline and the duration of 4+2 or 4+1 years for the undergraduate and graduate studies.

References: