Symposium
Challenges in Primary and Secondary Science Teachers Education and Training

Coordinators
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Introduction
GIREP Seminar in 2003 gave an important contribution to the problem of Quality development of teacher education and training, after the Barcellona Girep Conference in 2000 on Physics Teacher Education Beyond 2000. A number of important problems are yet unsolved and a wide research work has been carried out and documented (Abell, 2007). The Working Group 3 (WG3) of the EU-Project STEPSTWO (2008) is now facing this topic with the aim of sustaining Physics Teacher Education in universities, notably with regard to the trends in European Teacher Education, in order to reinforce the study of physics subject before university.

This Symposium aims at contributing to analyze and discuss some of the main problems of teacher education and training in physics, both in institutional perspective and in relationship to the curriculum updating and school reforms, by taking into account some main results of WG3 analysis. The professional development and the research perspective are the main aspects here considered for primary as well as secondary teachers.

Teacher education systems are very different in the European Countries: the Bologna process involves a revision of the University missions and the decision related to the link between academic and professional education. The Ministries of Education are discussing this question and it emerges the need of a comparison for some agreements, mainly in the perspective of the school reforms promoted in different countries.

At operative level, the main problems in teacher education are related to strategies and methods to develop Pedagogical Content Knowledge (PCK) (Shulman 1987) both in pre-service and in-service teacher education (Park, 2008). Some related main problems are: the lack of competences in content knowledge (CK); the difficulties of novices in putting in practice pedagogical knowledge (PK) in relationship with CK, the general difficulty to integrate PK and CK for PCK development, planning skills and coherence in teaching/learning paths. Open research questions are: how to stimulate and assess the development of appropriate PCK that includes methodological competences related to experimental exploration, modelling and building formal thinking as well as the ability to promote argumentation in discourse or teaching/learning approaches stimulating meta-reflection.

In the context of the WG3 analysis of the European situation (STEPSTWO, 2008), it has been pointed out that few physics departments and schools of education are actively engaged in the recruitment and professional preparation of physics teachers. Moreover, few institutions demonstrate strong collaboration between physics departments and schools of education and Programs do little to develop the physics-specific pedagogical expertise of teachers in order to achieve a cultural base in science education of teachers of all school levels.

The main problem is how to realize Programs for teacher education supplying educational tools for different situations and contexts aimed at improving teaching competences. Some relevant results have been pointed out by research and Examples of Good Practice. Some of these, mainly connected with pre-service teacher education will be analyzed in this Symposium.
Pre-service education requires to directly face teaching/learning problems of specific subjects. This objective can be achieved by means of teaching activities in which the planning as well as the reflection on didactical proposals are integral parts of the process. Moreover, the direct involvement is considered to be effective only when it is operative and tasks and goals to be reached are clearly defined.

The *Green Paper on teacher education in Europe* (Buchberger, 2000) highlights the crucial role of designing learning situations in which Trainee Teachers (TTs) can find opportunities to develop structures of meaning, knowledge and activities for a didactical reconstruction of the disciplinary contents, integrated with pedagogical competences, methodologies and teaching practices. This aspect will be outlined in the various contributions to the Symposium.

### 1. Challenges in Secondary Science Teachers Education

#### 1.1 Relevant elements of the challenge

The analysis of the Eurydice reports (1998, 2003) and the first results of WG3 analysis point out many relevant similarities and differences about two main points concerning Pre-Service Secondary Teachers Education. The first involves the structure of the Programs that, although having different characteristics, involve 5/6 years of university education and can be classified into two big categories: a) sequential education, where the pedagogical education follows the disciplinary education; b) parallel education where disciplinary and pedagogical education develop in parallel along the whole period of university instruction. Both the structures present advantages and disadvantages. However, almost all the countries are searching for new Programs and mainly new methods. The second point involves the nature and level of TTs’ physics knowledge; in fact, very often, their subject-matter understanding seems not the conceptual understanding they will need to develop in their future pupils.

In these last years, the idea of science education, at all school levels, is strongly changing and consequently a new way of thinking about teacher education is developing. It involves a new framework where the professional preparation of a science teacher is analysed in terms of *professional profile* in the context of jobs for “Human Talent Management” (Tigelaar et al., 2004). Such a profile is frequently described in terms of *competences* and this new word has been also used in most of the new international normative. The usual framework of literature assumes that teacher competences should include:

- Ability to address, master and manage specific knowledge/methods related to the area of interest.
- Capability to integrate different kinds of knowledge/methods in a flexible net.
- Ability to transform such a net of knowledge/methods in a synergic attitude into concrete doing.

This involves that the profile of an effective science teacher is strictly connected with practices. By comparing and contrasting data from partner’s of WG3, the following problems have been identified:

- Lack or insufficient knowledge of the discipline(s) which are supposed to be addressed in the teaching process.
- Lack of reflective practice, especially epistemological reflection about how science is constructed (Knowledge of the Nature of Science).
- The knowledge of the discipline supplied by the university curricula is, in many cases, focused on contents (laws, theories and models), more than on those processes which characterize the discipline and on connections with the real phenomena.
- Compartmentalization of the discipline that fails to make physics more relevant to students, more easily learned and remembered, and more reflective of the actual practice of physics.
Problems of teaching methods, that are essentially based on a lecture format and content approaches that are often thought as exemplifications of university courses. Such problems have been analysed by many research papers that tried to identify the main knowledge and abilities grounding the competencies of physics teachers. These identified requirements that would be explicitly addressed in the goals, objectives, readings, and assignments included in pre-service preparation. It becomes relevant to identify Examples of Good Practice supplying evidences and monitoring the growth of the TTs’ knowledge, skills and attitudes.

1.2 An Example of Good Practice

The interaction between CK and PCK has been the focus of several EU funded Projects. They developed guidelines for Programs and methods supporting the acquisition of the complex set of competences required to physics teachers. Looking at the Italian context, an example of good structure of TT Program is described in Fig. 1.

The structure stands at the center of the training process the laboratory of disciplinary didactics that integrates in a specific context the disciplinary knowledge and the pedagogical knowledge. The analysis of the school contexts, where TTs develop their apprenticeship, participates in the design of appropriate teaching approaches of well defined disciplinary fields, by interconnecting it with the curriculum and with the particular objectives chosen by the school.

Each laboratory/workshop is intended as a prototypal laboratory involving a particular disciplinary content and showing:
- the possible space (of objects, facts, observations, ) to navigate in order to successfully give meaning to the related conceptual content;
- the set of landmarks that can guide the individual understanding;
- the conceptual knots pointed out by Physics Education Research (PER);
- the models of common sense knowledge pointed out by PER;
- the critical details made evident in classroom practice.

The laboratory mainly involves TTs in activities, such as
- analysing pupils’ reasoning in order to point out mental models connected with their common sense knowledge;
- defining teaching and/or learning goals based on content analysis and diagnosis of students’ prior knowledge;
- designing lessons using PER-based instructional strategies;
- designing problematic situations;
- designing experiments and modelling approaches.

The main results of such laboratories focused on disciplinary didactics are published in many papers (see for example: Sperandeo-Mineo et al., 2006; Aiello et al., 2001). General results can be identified in:
- TTs’ awareness of deficiencies in their own knowledge of physics and pedagogy;
- appreciation of the need about a clear perception of their students’ knowledge;
• deepening of TTs’ knowledge of physics and physics pedagogy;
• a systematic research-based approach to the design of specific lessons.

Concerning the used methodology, we should like to outline the role of meta-reflection on their own learning in deepening of knowledge of physics as well as in pointing out the learning knots of the specific topics.

2. Challenges in Primary Science Teacher Education

2.1 Some elements of the challenge

Physics today does not attract young people; some ideas for such a lacking of interest meet a general consensus as, for example, that physics would be more appreciated if pupils start studying it early, or that it is taught superficially by only presenting facts and rules. If our mission is to increase the relevance of scientific knowledge for all citizens, we have to offer a good pre-service education to primary school teachers to this purpose. This is a challenge for all the European Universities and also for the Italian Universities, which have just started their own reform too, so as to conform to the Sorbonne and Bologna agreements.

Relevant elements of such a challenge are:
• The lack of TTs’ competencies of in CK.
• The difficulties of novices in putting in practice PK in relationship with an appropriate CK.
• The general difficulty to integrate PK and CK for the PCK development.
• Competence in the construction of coherent teaching/learning paths.

Several EU funded projects have addressed such main problems of teacher education from different viewpoints: hands-on experiment, lab-work, contributions from ICT and ET, informal education,… in order to gain possible common frameworks based on experimented Examples of Good Practices.

2.2 An Example of Good Practice

An experiment has been carried out in the Degree Course of Primary Teacher Education at the University of Udine, that implemented the development of an Exploratory Laboratory, involving experiments and analysis of cognitive paths of both TTs and pupils, before an overall view relating to the specific subject. This work moves from the assumption that pre-service training requires education in the discipline, through the teaching of the discipline itself, and that this objective can be achieved by involving TTs in teaching/learning activities in which the planning as well as the reflection on didactical proposals are an integral part of the process.

Various strategies, based on such hypotheses and characterized by being set in real situation and realizing operative involvement, have been selected. Not completely defined instruments have been offered, since the elaboration and the planning phases are considered a part of the intervention, therefore integrating professional and disciplinary education.

The basic tasks were made by some activities of the “Games, Experiments, Ideas” exhibition (GEIWEB, 1999; Michelini, 2003, 2004) for informal learning. The physics fields explored in the different sections of the exhibition (especially the one on thermal phenomena where on-line sensors are used for real-time acquisition and plotting of evolution of temperature) offered different didactical proposals to be analysed and elaborated in order to plan single experimental activities or differently organized learning paths.

As far as methodology is concerned, TTs were requested to perform their activities carrying out the PEC cycle: prediction of what is going to observe, verification of hypotheses by means of experimentation, comparison of hypotheses with the experimental results and, if needed, formulation of a new hypothesis. No specific instructions were given about the kind of predictions to be made (qualitative as well as quantitative).
The GEI materials have shown to be suitable for the adopted formative intervention, since they favour the personal involvement of TTs, their “putting themselves to the test”, their “learning by experiencing”. Physics education in a context that results funny and very similar to everyday life, confers to the discipline a power of link with common experience which makes the student recognize its cultural value as well as its utility. It gives to physics relevance in improving the personal capacities of observation and the understanding of common phenomena. Finally, the didactical materials of the exhibition are valuable guides for formalization and abstract thinking.

The analysis of results has been centred on the improvement of critical and planning capacities for the construction of professional competences in physics education (Michelini, 2003, 2004), with particular care on the planning of single experimental activities, of explorative experimental chains and of maps and conceptual networks for the definition of paths for the management of formal instruments, either for personal exploration or for didactical proposal definition.

TTs have shown explicit consciousness of the needs of acquiring practical and disciplinary competences, as well as those of assuming methodological and didactical abilities. This stimulated their interest for physics and for its learning and, consequently, teaching to pupils during their apprenticeship. The observation of children and, then, their guiding in the visit to the exhibition supplied TTs with essential didactical elements. On the other hand, the personal involvement in experimental activities introduced them to the development of a scientific and rigorous way of considering real phenomena. In this sense, the activities based on the GEI exhibition have stimulated the acquisition of consciousness of the role played by instruments and methodologies in the learning/teaching process (as in the cases of the construction of appropriate didactical paths).

3. Conclusion and some general implications

In conclusion, we outline some suggestions or keywords for a possible/plausible EU common framework for teacher education. Firstly some main objectives that should be aimed at and secondly some framework features which have to be taken seriously into account.

A broad objective is to have science teachers firmly convinced of the necessity and value of enriching their disciplinary content knowledge and of transforming it into a pedagogical content knowledge suitable for teaching. Another objective is to have science teachers with sound competencies in the infusion of Educational Technologies across the curriculum. A teacher with such competencies uses personally these tools and understands how and when they are appropriate in science education. For example: - integrated use of real-time lab-work and modelling activities to foster/support links between phenomenology and formal thinking; - extensive use and construction of dynamic images in order to exploit visual knowledge so as to facilitate the study of familiar and complex physics phenomena and of their mathematical description. These types of approaches, not related to a specific subject but of transversal nature, require in teachers a deep awareness of the approach rationale and sound skills to guide toward convergence the open class dynamics that is usually triggered.

Amongst the main framework features to cope with, the coherence with the 1999 Bologna declaration is important. The university disciplinary curricula are not yet completely shaped by it, so it is crucial to have a teacher education resonant with “promotion of the necessary EU dimension in higher education”. The results of educational research should be transformed into ingredients of the training Programs, aiming at improving the impact of research on ordinary class practice. The interaction with education authorities (local or central) is crucial to: define priorities, strategies and contents of science education innovation; build, test and propose models/materials; foster and support the take-up of innovations.
References


