Chapter 4
Physics Teachers' Education (PTE): Problems and Challenges

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Abstract A vast majority of the research results acknowledge the crucial role of teacher's education, as a vital tool in enhancing the quality of physics education. The projects like PISA, ROSE and TIMMS showcase the impact of teacher's education as a qualitative improvement in the physics learning environment. In Physics Education Research (PER), the impact of teacher's education had been addressed for the its role in the enhancement of positive interest among the students. The current world-wide state of the art characterizes a large variety of boundary conditions, traditions and practices that are being followed. In our present context, we foucus and discuss on the multidimensional challanges such as competencies needed, degrees required, problems encountered, support to be provided and the basic pre-requirements of Teacher's education for the secondary schools. We present some of the teaching methods and practices followed in coherent with, both, the Student centered and open learning environments along with some of the useful didactical indicators. Also, we potray a couple of research-based examples successfully experimented in Italy. Finally we propose some useful recommendations along with the criteria to be followed in the teachers education for the overall improvement.

4.1 Introduction

This paper discusses different aspects of Physics Teachers' Education (PET), especially the problems highlighted by international survey studies on students' achievements and teachers' characteristics; the links between Physics Education Research

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and Teacher Education; some research-based example interventions; a proposal for a EU Benchmark for physics teaching degrees. The discussion addresses the complex challenge linked to improving the quality of physics teacher preparation, both pre-service and in-service and suggests some recommendations. The strategic role of teachers in the learning processes is well acknowledged; together with students they are key actors of any project aimed at improving scientific education and deeper awareness of the future of our planet. Physics is crucial in describing, modelling, understanding the natural world; teaching and learning physics involves many different dimensions (disciplinary, cultural, historical, social…) and many links with other disciplines. The focus on PTE at school level in the so-called industrialised countries is motivated by at least three different reasons:

- Young people have goals, interests, ways of learning, lifestyles, … that differ in many respects from the people used to refer mainly to printed materials; the same holds for capabilities about Internet, social networks, combination of formal, non-formal and informal education.
- The key concepts, needs, requests of the Knowledge Society are receiving increasing attention in many countries. In this framework, scientific knowledge/education is assuming a growing importance, also as a condition for being aware of and deal with complex socio-political issues, e.g. climate changes, energy, health, …
- Despite the increasing use of technology in education and the growing momentum of informal learning, teachers remain key actors in education. There are many factors and issues related to the profession of teacher (such as the vision of the teaching/learning processes, the increasing number of competences required, the pre-service and in-service education programs, the current teaching practices, the common perception of social role of teachers, ...) which require considerable attention and specific actions.

4.2 Students’ Achievements and Teachers’ Competencies

Data and analyses come from several studies[1], e.g. in alphabetic order: National Task Force on Teacher Education in Physics (NTFTEP, USA); PISA; ROSE; STEPSTWO; TIMSS and Physics Education Research. The main features of students’ achievements and teachers’ competences induce to reflect on several aspects of the con-

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[1] National Task Force on Teacher Education in Physics (NTFTEP, USA) http://www.ptec.org/taskforce OECD Programme for International Student Assessment PISA PISA www.pisa.oecd.org/ every 3 years 15 years students assessed in Reading, Mathematical and Scientific literacy PISA 2009: 34 OECD members +41 partners countries, *PISA 2009 Results: Executive Summary* ROSE The Relevance of Science Education ROSE http://www.uv.uio.no/ils/english/research/projects/rose/ STEPS TWO Academic Network (2008–2011) http://www.stepstwo.eu/ To support Physics Depts. in post Bologna processes, student-centred/flexible learning, Physics Teacher Education in Universities, to reinforce the study of Physics at Secondary Level Universities from 27 Countries + 7 Associated (Five Universities, EPS, EPSI) TIMSS Trends in International Mathematics and Science Study http://www.timss.bc.edu/TIMSS 2007: 59 countries, six benchmark

struction of a sound scientific knowledge. The achievements in science and physics at secondary school (4, 8° and final year) indicate various problems and difficulties. TIMSS Advanced 2008 indicates that Mathematics and Physics programs vary in duration and intensity (2–5 years, 100–200 hs/y), with generally fewer instructional hours in Physics. A large gap divides the highest and lowest performing countries, with a wide range between the highest and lowest achieving students. In Physics the Netherlands was the top performer; Slovenia and Norway had very similar average achievement. These three countries, together with the Russian Federation, had higher achievement in Physics. The measured change in average achievements (1995–2008) in advanced Mathematics is small in Russian Federation and negative the other three countries . In Physics, Slovenia had essentially no change, some decline for the other three countries. In most countries, the majority of students were males. The PISA 2009 comparison of countries with respect to the OECD average indicate several countries from the East (Hong-Kong, Korea, Shanghai, Singapore, Taipei, Japan) amongst the top performer on both Mathematics and Science scale, together with Canada, Australia and New Zealand. In Europe Finland, the Netherlands, Norway, Germany, Belgium and Denmark do rank well, better than USA; Italy is below the average. The ROSE project (The Relevance of Science Education, 40 Countries in 2010) does not test achievement, it addresses factors of importance to the learning of science and technology (S&T), as perceived by students (about 15 ys), "to contribute to improve curricula, while respecting cultural diversity and gender equity and empowering the learner for democratic participation and citizenship". Results from ROSE show that: students in rich countries, especially girls, have attitudes toward science and scientific careers less positive than those surveyed in so-called developing countries; in Northern EU and Japan they are more ambivalent than adults; girls, in the richest countries, are more negative or sceptical than boys; very many students, in poor countries, want to become scientists and have not this possibility.

On teachers' side, the problems come mainly from three areas: policy and organization, insufficient competencies, inadequate exchange between school and PER; their solutions present interesting challenges. Some are related with institutional aspects, as the features of the educational system (e.g. centrally vs locally decided curricula and syllabuses, teachers as State employees versus recruitment by the school, …); the status of Physics when taught as a single discipline or as part of combined science; the role of Universities and Physics Department in the pre-service education; the different standards for being a certified teacher; the recruitment procedures; the type of the agencies entitled to run programs for in-service teachers education and the contents of PTE programs, etc. Other challenges derive from the shortage of qualified physics teachers (in several countries; the transformation of the indispensable subject matter knowledge (SMK) into a richer pedagogical content knowledge (PCK) that includes applied pedagogy and PER results; the insufficient acquisition of the rapidly

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(Footnote 1 continued)
participants; 4 and 8° grades; about 434,000 students; 47,000 teachers, 15,000 school principals TIMSS ADVANCED 2008 (students in last year of secondary school taking or having taken courses in advanced Mathematics and Physics: Mechanics, E&M, Heat&Temperat., Atoms, Nuclei. Ten countries: AM, IR, IT, LB, NL, NO, PH, RU, SI, SE. Changes tracked in 1995–2008: 5 Countries.

increasing number of competences (in physics, physics education, pedagogy, ICT, communication, class management, team-work, etc…) requested to teachers and school system in order to cope with the changes in society and in students' interests and attitudes; the scarcity of resources devoted to programs for continuous teachers professional development (funds, design/implementation capabilities, effective evaluation, …); intrinsic inertia of well-established and ineffective teaching practices; insufficient implementation of validated innovations; … Other challenges are linked to realise concrete ways for: enhancing PTE with knowledge and active experiences of the most significant results of PER (e.g. common and robust learning difficulties, teaching rituals that may result in lack of understanding, …); experimenting the advantages and limits of Technology Enhanced Learning (TEL); constructing multi-faceted supports for both pre and in-service education and for on-field teaching in standard conditions and contexts. The complex problems of the current PTE are well represented in the Report 2010 of the National Task Force on Teacher Education in Physics, by American Association of Physics Teachers, American Physical Society, American Institute of Physics. It states that: "Except for a handful of isolated pockets of excellence, the national system of preparing physics teachers is largely inefficient, mostly incoherent, and massively unprepared to deal with the current and future needs of the nation's students…. Physics departments, schools of education, university administrators, school systems, state agencies, the federal government, as well as business and foundations, have indispensable collaborative roles to play so that *every high school student has the opportunity to learn physics with a qualified teacher*…. .... Science education in the United States lags well behind much of the rest of the world, and in some cases, the gap is growing.... more students than ever before are taking physics from teachers who are inadequately prepared. There is a severe shortage of qualified physics teachers…. many current physics teachers lack the content knowledge and focused pedagogical preparation with which to help their students most effectively: international assessments show time and again that U.S. students lag behind their counterparts in other industrialized nations.... the shortage of qualified teachers is especially severe for those students who take either conceptual physics courses or physics as a gateway to other sciences in high school….“ —a group of students that has experienced the largest increase in size in the last several years".

The 2008 TIMSS ADVANCED results on secondary school Physics teachers (10 countries: AM, IR, IT, LB, NL, NO, PH, RU, SI, SE) indicate a complex scenario. The main area(s) of education are Physics, Mathematics, Chemistry, Engineering, Biology, Education (in Italy: 40 % Phys, 50 % Math, 10 % Eng). The requirements for being a teacher are diverse: Bachelor; Master plus Education course; Certificate Higher Education; Physics studies plus Education plus one year of supervised teaching. The collaboration with teachers of other disciplines varies much, from almost never to 2–3 times/month to once a week (in Italy: about 46, 49, 5 %). The book is still the main educational tool used, in about 100 % of the surveyed countries; in more than half of the time in school the students read "theory" or how to do exercises. The demonstrations of experiments ex-cathedra are common and vary from 11 to 54 %, experiments or investigations done by students from 0 to 30 %, use of calculators and computers from 0 to 50 %. In our experience the difficulties associated to an effective use of ICT and TEL based learning environments are less and less linked with shortage of hardware and software, the insufficient educational competencies for an effective use being the real bottleneck.

Answers to the above challenges can come from the links between PTE and PER; PTE is a research field which has been addressed in depth since long time. The main topics dealt with are: Teaching–Learning Processes (teachers' naïve epistemologies, deeply rooted and ineffective practices, common and robust learning difficulties linked to students' (and sometime teachers') naïve ideas and reasoning that conflict with Subject Matter Knowledge; …); ways to effectively transform Subject Matter Knowledge in Pedagogical Content Knowledge, focusing on its construction in PTE programs; the role of lab-work and the associated approaches, proposals and materials; modelling and simulation activities, support by multi-media; validated strategies to encourage/implement active and critical learning (e.g. Prediction–Experiment–Comparison learning/teaching cycle); experiential modality of a PTE activity (to do personally and in detail what will be proposed to the students); critical analysis of transformations of research-based proposals made by teachers and students in standard contexts and conditions; models and experimentation of prototypes of PTE programs (pre and in-service), etc… For sake of brevity it is not possible to discuss at length all these aspects.

4.3 Research-Based PTE Interventions

The rationale of a research-based PTE program is multi-dimensional. A not exhaustive list of key points has two levels. (A) the integration of different knowledge domains such as *(i) topical knowledge* about specific topics: crucial concepts about a phenomenon, its regularities, aspects, interpreting model(s), laws, applications, design/run of experiments; *(ii) net-worked knowledge* that links various types of concepts and skills; *(iii) meta-knowledge* i.e. the capability to build new theoretical and experimental knowledge); *(iv)* the acquisition of multi-competences (e.g. application of knowledge, independent learning, analytical and computational capabilities; ability for criticism, synthesis, communication and teamwork). (B) Focus on: -not-yet-much-common teaching methods (e.g. student centred and open learning environments, problem and project based procedures, peer instruction, …); -experimental activities via various types of lab-work (in presence with real-time sensor-based experiments and ready-to-go apparatuses, remote-controlled-experiments, virtual lab); -support by multi-media (extensively interpreted in); -links amongst phenomenological observations, data, abstract formal representations, modelling activities and theoretical reflections; -strategies to feed and enhance students' interest and motivation.

Hereafter we briefly discuss four emblematic examples of TE in Physics. The first two have been designed and implemented at University of Udine on energy for perspective primary teacher education ([2]) and on quantum mechanics basic concepts for in-service teacher in upper secondary school ([3]). The others are Projects and initiatives taken by international entities: Physwere by ICPE and Muse by EPS-PED.

4.3.1 Energy Intervention Module for Prospective Primary Teachers Education (FIME)

The Formative research based Intervention Module about Energy (FIME) was proposed in two different groups of 250 Prospective Primary Teachers (PPT), 21–22 years old, in two years at University of Udine. FIME include a preliminary subject centered part (CK) and an innovative proposal about energy for primary school, based on simple qualitative exploration and inquiry strategy by means of tutorials. To educate PPT to the Energy concept two different kinds of problems have to be overcome: (a) the lacks in the disciplinary knowledge [24, 27, 47] and in particular the identification of energy as a state property of a system; (b) the way of thinking to the pedagogical approaches only related to forms of Energy and to Energy sources, typically adopted in the textbook.

The sample was composed by N = 101 PPT in the first experimentation and by 143 PPT in the second one. An additional Conceptual Lab activity involve 37 of the PPT of the second group.

The first year FIME was organized in the following parts: (1) Pre/questionnaire (1 h), (2) Discussion on the foundation in physics of the concept of energy in traditional way and analysis of the main concepts and consequences related to: kinetic energy theorem, energy conservation principle; the first thermodynamic principle (4 h), (3) Collection of the questions posed by PPT on energy and relative discussion (1 h), (4) Presentation and discussion on the rationale of the research based proposal on energy developed [21], with illustration of the simple everyday experimental apparatus and explorative activity (4 h), (5) Post/questionnaire (1 h).

The post-questionnaire composed by 15 open ended questions was proposed to the PPT after the instruction to evaluate the PCK, during the final examination. The questionnaire was designed on the following main conceptual knots emerging from literature: energy associated to human or living being, as fuel-like substance which is possessed by living things; energy possesses only by moving objects (Stead 1980. Watts 1983) or as product of some process and existing only during this process ([35]; Watts 1983; [11]); energy; energy as force or power (Trumper 1983, [10]); different forms of energy and recognition of the form associated to standing objects (Brook and Wells 1988; Carr and Kirkwood 1998); conservation of energy (Duit 1981; Watts 1983; Black and Solomon 1983. Brook and Driver 1984. Driver and

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[2] Heron et al.[20]

[3] Michelini M, Santi L, Stefanel A (2011), Teacher discussion of crucial aspects, cardinal concepts and elements peculiar to Quantum Mechanics starting from an educational proposal, in Battaglia et al. [3]

Warrington 1984, [46]; transformation of energy and process (Carr and Kirkwood 1998; Gilbert and Watts 1983; Duit [11]; Trumper [49] Dawson-Tunik 2005).

The format was a set up in two parts: (I) a CK question; (II) the typical answers of 4–5 students to the CK question posed and the request to describe the characteristics of the students' ideas and "what teacher have to do" for each student.

From data analysis it emerged that 87 % of PPT use the types of energy to give an appropriate description of simple processes in terms of kinetic, potential, internal energy; only in few cases 30–35 % are present difficulties in distinguishing potential energy and internal energy, in some case the energy associated with light. Analogous percentage we obtain for what concern the identification of energy as quantity that is transformed from a form to another and that is conserved. Concept of transformation and conservation are often associated ("because it is transformed"). For a group of PPT (about 40 %) the transformation is in any case associated to a dispersion or a loss of energy. This results evidence an important modification in the initial conception about energy with respect the results of the pre- questionnaire. Another picture emerge, when the Pedagogical Content Knowledge (PCK) is considered, analyzing in particular the teacher plan on how propose energy to the pupils, how they organize the topic for school, and ideas expressed in oral examinations. A large majority of PPT recover the initial ideas and conception when they have to think educational activity and paths for pupils. For instance about 72 % mentioned as a first goal the wrong definition of energy, frequently proposed in the textbooks: "Energy is the capacity to do work". At the same time one of the most diffused aim was to teach to pupils that "It exists in different forms: nuclear, kinetic, thermal……", without any distinction between type and forms. About this point the more evident change was that a large majority includes forms of energy: kinetic, potential, internal and the usually quoted energy forms related to sources solar, hydroelectric, nuclear, wind energy. Also an ambiguous language was used in some case (es example "it is transformed (for instance in the movement of a turbine)") or an assertive approach was used (for instance: "It is conserved <<nothing is destroyed, nothing is conserved>>"). This results confirm that a reconstruction of the concepts and a proved CK do not produced effective changes in the pedagogical organization of the educational proposals..

For this scope, in the second year the FIME was restructured to include personal reflection and successive group discussion on the main conceptual nuclei and knots about energy. For a group of 37/143 PPT a PCK lab was carried out using papers on learning problems taken by literature for design based educational path proposals by PPT. PCK-lab imply a personal reflection activity on CK aimed to discuss pedagogical aspects.

The main Research Questions in second year of FIME study were how sort of contribute to the PCK formation on Energy produce in perspective primary teachers a strategy based on:

1. exploration of an innovative teaching/learning proposal on energy?
2. personal involvement in the analysis of conceptual knots and learning questions combined with a pear to pear discussion?
3. What kind of PCK?

From an intermediate questionnaire emerge that improvement was obtained in the CK: Energy is identified as a state properties of a systems (83 %), that can be transformed (87 %) and the process is described in terms of actions and in terms of energy (75 %). A great personal involvement was needed to transform the content competences in professional attitudes. In this process the role of peer collaboration and of idea comparison were relevant. In particular a personal involvement in the analysis of PCK questions combined with a peer to peer discussion build gradually effective PCK on energy for the small group of PPT (37). A relevant contribution comes from the knowledge of typical students learning problems on the topic and how it is possible to face in school classroom (32/37).

Data emerging from the questionnaire answers are crossed with those obtained by tutorial worksheets filled during the PCK lab, the portfolios of the prospective teachers and the discussion in large group about the educational path. Results evidenced a relevant and generalized increasing about the CK, as well the PCK. The way to build and monitor the PCK competences and to act for their improvement for PPT appear to be fruitful in the identification of the way of thinking (34/37). The integration of research results in the FIME offers the opportunity to enrich the formative module not only with respect to the CK competences, but also for those of PCK.

4.3.2 Research Based Quantum Mechanics Formation for in Service Teachers

This second example of research based intervention module is on in-service teacher (IT) education on quantum mechanics in the framework of the Master on Didactic Innovation in Physics Education and Guidance (Master IDIFO) for in-service teacher education, now at 4th edition from 2006. Master IDIFO4 is instituted at the University of Udine with the cooperation of more than 20 Italian Universities as a two years activity for 60 cts organized in blended modality, being the main part in e-learning with intensive workshops on campus. For e-learning activities a specific web environment was developed. The formative activities are structured in four Training Areas (general, characterizing, project-oriented and on site) which are set out in five thematic Modules: (A) quantum physics (18 cts); (B) Relativity (12 cts); (C) statistical physics and material sciences (15 cts); (D) nuclear physics, particle physics and cosmology (2 cts); (E) Formative guidance and problem-solving as an operative challenge for guidance (6 ctsfu). Each Module include: (a) e-learning formation done by a responsible of the specific course included in a Module, by means of the material that has been selected and assessed according to research outcomes (30 cfu); (b) experimental laboratory activities (4 cfu); (c) three intensive on campus Workshops of 6 cts (approximately 60 hours) at the University of Udine; (d) planning activities for teaching / learning intervention on didactic innovation (7 cfu); (e) teaching–apprentiship: didactic experimentation activities: four activities of at least 6 h on Modules A, B, C & D, E respectively (7–11 cfu).

A particular focus in each course is on the discussion of didactic proposals, the analysis and evaluation of results related to research questions brought to light by didactic research into the various themes under investigation: individual and group discussion has been favoured.

The formative model individuated with the Master IDIFO integrate cultural, disciplinary, didactic and professional aspects. It is considered by the teacher-students participating as the most efficacy and corresponding to their needs. In particular it combines 'metacultural' approach with an experience-based, on situated ([4]) training method, offering each person the chance to develop a project according to his or her needs and motivation.

The rationale for teaching /learning paths in quantum physics for upper secondary school is widely discussed. The Dirac approach to quantum mechanics (QM) was discussed with teachers starting from an educational proposal for secondary school. The QM way of thinking was analyzed in a community of teachers and researchers. The research on teacher education carried out in this framework was focused on the following questions:

RQ1. Which are the most problematic knots regarding QM in a group of high level teachers?
RQ2. Which difficulties one faces in a teacher education based on a new proposal of QM teaching?
RQ3. Which learning paths results more effective for a real improvement of PCK?
RQ4. How do teachers modify the proposal of reference when asked to design a didactical path?

The 22 teacher involved had a long teaching experience, except for one, that is employed in an optic industry. The educational module is subdivided into three main steps:

1. Course A focused on the presentation and discussion in web forum of the knots on which the proposal of reference is developed and of the working sheets which are integral part of it.
2. In-person meeting for discussing with the teachers on the rationale of the proposal itself and the unsolved knots remaining after the web forum discussion.
3. Course B constituted by a web didactical laboratory, aimed at designing a micro module focused on the reference proposal analyzed the previous steps.

In a pre-questionnaire teachers have to list three topics on QM of particular interest for high school students, explaining the reasons of the choice (Q1) and to two elements characterizing quantum mechanics behavior with respect to classic mechanics, explaining the reasons of the choice (Q2). The maps produced by teachers for the educational design at the end of the activities were analyzed on the light of the aspects emerged in Q1 and Q2 and the discussed aspect in the community.

In the data of Fig. 4.1 the radical change in contents considered important by IT for the developing of the didactical proposal is clear. In the lists of tasks Q1 and Q2

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[4] Michelini [30]

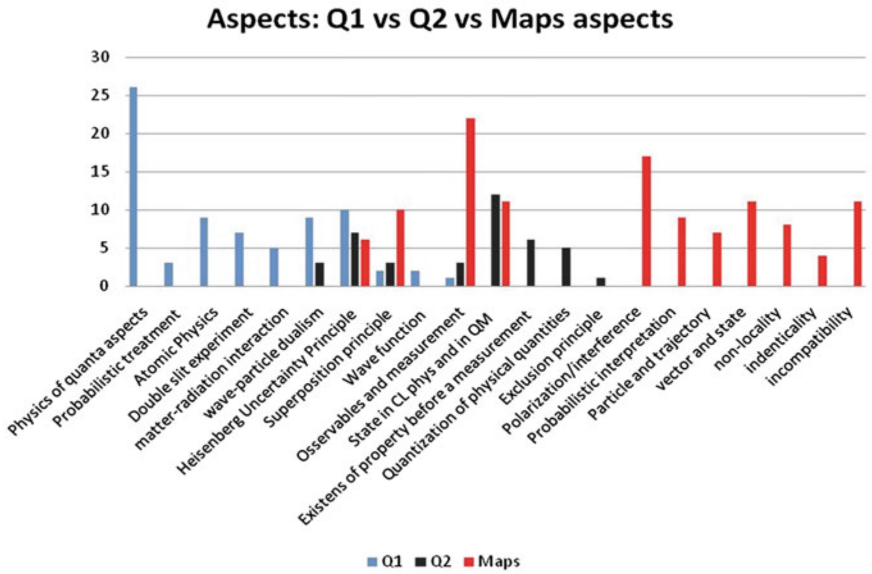

Fig. 4.1 Aspects emerged by Q1 and Q2 inquiry and from Maps prepared by IT to describe the rationale of the planned paths for a teaching/learning intervention on QM

the predominant category refers to aspects of quantum physics but few of these are characterizing elements of QM as a theory; in the categories emerged in the final maps only the basic aspects of the theory are emerged. What can be clearly seen is the pre-eminence of the polarization context, underlining that for 12 teachers the reference context stayed the one of the polarization, for other five the context of diffraction and spin (not present in the diagram because its frequency is two) are also introduced.

From data it emerged that even well prepared teachers have a vision of the teaching of QM physics of quanta oriented (RQ1). The indetermination principle is considered a key one in QM, likewise, for many other student-teachers, the quantization of physical observables (discrete spectrum).

The main difficulties encountered (RQ2) on the learning path are about leaving context usually explored with high school students, in particular the indetermination principle for position and impulse, the context of free propagation, rather that contexts of two-state systems which are simpler.

The elements of the learning path that led to the main changes in PCK (RQ3) are: (a) the didactical proposal offered for discussion focused on facing the basic concepts of QM and on the detailed analysis of the instruments, (b) the rich exchange developed on the web between the student-teachers and between them and the tutors about the different basic concepts of QM followed in the reference didactical path, (c) the direct involvement in the construction of conceptual and organization maps of contents and work modalities. In particular, the main changes are the passing from a vision focused on the physics of quanta, to a vision in which a central role in the quantum theory is covered by the superposition principle.

In the designing of personal didactical paths, even if the superposition principle plays a basic role for most of the student-teachers, the attention is mainly focused on the measurement theory and on the concept of state. In the specific case of high level competence student-teachers, the main integrations are about other phenomenological contexts with a similar approach to the one proposed, like the one of the spin and the diffraction phenomenology (RQ4).

4.3.3 PHYSWARE Model Workshops

The third example is PHYSWARE, by International Commission of Physics Education (ICPE), held at International Centre for Theoretical Physics, Trieste Italy (2009, 16–27 Feb) http://cdsagenda5.ictp.trieste.it/full_display.php?ida=a07137. It has been "designed to enhance the quality of physics education at the tertiary level, especially in the developing countries, conceptualized as a series of model workshops and resource materials for physics teachers and teacher trainers that exemplify how active learning methods can be adapted to meet the needs of students in developing countries , to provide materials at the undergraduate level using affordable hands-on equipment that can be locally adapted by teachers and their students, to offer exposure to appropriate technologies and computer-based tools for enhancing conceptual understanding ..., to provide a forum to the teacher-leaders to share experiences and exchange ideas about dissemination of active learning methods". Newtonian Mechanics was the theme for PHYSWARE 2009. Out of more than 200 applications from 48 countries, 35 participants were selected from 27 countries in Africa, Asia, Latin America and Europe. The ten working days workshop has had four session of 1.45 h on each day plus seven 2 h post dinner sessions for posters and discussions, involving the participants in research-based conceptual tests , diagnostic tools and learning cycles promoting active engagement. The first week activities focused on lab-work and class activities using no-cost, locally available materials (e.g. pendula of different lengths as clocks to measure time in arbitrary units, a mahogany flower pendulum to study damping). In the second week the participants worked collaboratively on didactic projects using motion and force sensors, photo-gates, video clips and simulations. All materials used are freely downloadable at the above site. Issues of multicultural and multiethnic classroom were also discussed. A Discussion Group and a Blog have been realised by the participants in addition to the PHYSWARE Workshop site at the ICTP portal and the Wiki created by the directors. Feedback from participants' evaluation has been extremely positive. A five year action plan with ICTP has been agreed, for workshops to be held in Trieste and in developing countries.

4.3.4 MUSE Project

The last example is MUSE (More Understanding with Simple Experiments), a project started in 2008 in the framework of European Physical Society—Physics Education Division (EPS-PED) http://education.epsdivisions.org/muse . The purpose of MUSE is to contribute to: awareness of relevance of physics in nowadays culture; interaction amongst school and university; better quality of physics teaching/learning by addressing physics and teacher education, new methods/ practices, differences/similarities in the European educational systems; ... MUSE offers research-based, free-downloadable materials (nine up-to-now). The Added Value in Education (AVE) addresses: cognitively dense and easy-to-assemble experiments using low-cost and easily available materials; Prediction Experiment Comparison learning cycle; variation approaches (what happens if … is changed?); identification/analysis of diverse viewpoints; interactive cognitive dynamics via peer learning; naïve ideas/reasoning conflicting with physics knowledge; learning difficulties studied by PER and plausible underlying reasons; teaching rituals resulting in misleading argumentation. The audience aimed at are teachers, the communities of Physics Education, Physics Teacher Education, Physics Education Research, Educational Authorities et al. To present the MUSE approaches with in-presence activities, two workshops held at the GIREP-EPEC 2011 Conference in Finland have involved about 35 participants with success and interest.

4.4 Some Recommendations for PTE

They can be grouped in three main areas. The first area deals with "experiential modality", i.e. teachers have a personal experience of the situations they will propose to the students as: strategies, approaches, methods, activities, tools, assessment. The goal is to experience in terms of "hands and minds on" with the most didactically effective experimental methods and techniques, modelling and simulation activities, student-centred learning environments, structured collaborative projects. The second area has to do with the time-scale of PTE that most often is concentrated in a small numbers of (isolated) training episodes rather than being designed as a continuous process lasting for the duration of the teaching activity thanks also to the opportunities offered by ICT and TEL. Communities of practice foster the process of sharing common problems and their solutions. Commented repositories of best practices, developed in standard contexts, allow sharing patrimonies of knowledge, expertise and innovation. This process of autonomous education, together with a series of in-presence episodes, can realise a continuous professional development program. The key words are: cooperation, collaboration, synergy amongst school, educational agencies, Universities.

The third area refers to the many contributions offered by PER to acquire crucial competences, as. e.g., to re-build zones of SMK, to construct PCK, to address naive ideas/reasoning conflicting with disciplinary knowledge, to integrate diverse types of knowledge, to effectively and wisely use the increasingly research-based and technology-based proposals. Modern physics in secondary school require innovation in contents, strategies and methods and PTE imply a change in the way of thinking professional work by teachers: a long process is necessary and teachers have to be supported. The challenges are many, great and complex, deriving from the various problems/difficulties affecting PTE; therefore they are appealing and call for a great, focused effort by the communities of Physics Education, Physics Teacher Education, Physics Education Research and Educational Authorities.

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