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Primary, Secondary and University pre-service physics teacher Education.

Dialogue 1 – GIREP-MPTL Conference in San Sebastian

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Introduction

Teacher Education in Physics (TEiP) is a problem of different nature in the different levels of education (instruction and formation) from kindergarten to university. Research results from Physics Education Research (PER) at international level and from European Projects, underline the crucial role of TEiP in enhancing the quality of physics education (Sassi E et al . 2014).

The projects PISA, ROSE and TIMMS¹ developed case studies showing evidence of the impact of teacher's education as a qualitative improvement in the physics learning environment.

The problem of TEiP is a multidimensional challenge involving the competencies needed, the problems encountered up to now, the supports to be provided and the basic pre-requirements of teacher's education for the primary, secondary schools and for university innovation.

In the past PER offered studies and results mainly related to physics teacher at secondary level. GIREP in particular promoted studies on TEiP since from its 2000 Conference in Barcellona (Pintò R et al 2001).

The meeting of European Ministries of Education in Portugal produced in the same year the *Green Paper on teacher education in Europe* (Buchberger, 2000). The Green Paper highlights the crucial role of designing appropriate teaching/learning situations in which perspective teachers can find opportunities to develop the main professional skills as well as a basic scientific culture which may enable them to perform successful educational design in spite of their limited knowledge of the subject. The suggested basic activities for teacher education are the following: Educational reconstruction of subject matter, Problem Solving situations, Research based curricular design, Planning Teaching/Learning interventions, Learning knots analysis, Students reasoning analysis in T/L activities.

From the GIREP Seminar held in Udine in 2003 on *Quality development of teacher education and training* (Michelini M 2004a) three main recommendations emerged: 1) *Specific professional programmes for teacher education have to be organized in all Countries*, 2) Didactic research have to be integrated with teaching and teacher education, 3) Cooperation between school and university have to be organized for the quality development of teachers. In the Udine Seminar we find contributions on the problem of primary teacher education on scientific level and in physics in particular (Corni F et al 2004; Michelini M 2004b) and on research based intervention modules on this problem (Michelini M, Rossi PG, Stefanel A 2004).

The studies on TEiP carried out in the framework of GIREP are a lot. In the following we present the milestone from Barcellona congress in 2000 up to Dialogue initiative in San Sebastian (2018). First we discuss here the special case of the Italian programme for teacher education, because it present interesting approach to the teacher education problem, due to the fact that it take into account research results in that field, the only advantage produced by the late activation in the 2000 year². We focus here in particular on the recent research based implementation of primary teacher education in physics in Italy.

Italy as a special case in teacher education and primary teacher education in physics

The primary teacher education in each scientific subjects, as in physics, is particularly important in Italy where a recent reform promoted by Luigi Berlinguer, the Ministry of Education launching the Bologna process for university reform too, introduced a teacher education programme both for primary and secondary school teachers.

¹ PISA 2009: 34 OECD members + 41 partners countries, *PISA 2009 Results: Executive Summary*; (OECD Programme for International Student Assessment PISA [PISA www.pisa.oecd.org/](http://www.pisa.oecd.org/) every 3 years 15 years students assessed in Reading, Mathematical and Scientific literacy; ROSE The Relevance of Science Education ROSE <http://www.uv.uio.no/ils/english/research/projects/rose/>; TIMSS Trends in International Mathematics and Science Study <http://www.timss.bc.edu/>; TIMSS 2007: 59 countries, 6 benchmark participants; 4^o and 8^o grades; about 434,000 students; 47,000 teachers, 15,000 school principals. See Sassi E et al 2014).

² Was It activated only in 2000, but the need of teacher Education was established by the law in 1945.

Secondary teacher education in that programme was organized by means of 2 years of Specialization School post Master degree for each teaching matter. It was organized in the following four areas of the same weight (25-30/120 credits) for teaching habilitation: 1) pedagogy, psychology and socio-anthropology, 2) Subject education, 3) educational laboratories, 4) Apprenticeship. The Content Knowledge (CK) of the subject was considered a pre-requisite controlled by means of an entrance exam. In each area the prospective teachers were asked to have an exam every 6 credits and a final exam on a teaching practice thesis. This very good project was formative for the university itself, not yet prepared for the teacher education. A few years later the political situation changed and the new Ministry of Education transformed the secondary teacher education in a one year long post-master. Another change in the national policy modified once more the situation and now Italy has a very bad situation for what concerns secondary teacher education: we hope to be able to discuss in the future a better programme.

This is not the case of primary teacher education, which is an excellence up to now. For primary teacher education, Italy has a 5 year long university specific degree³. The primary teacher degree includes 78 credits (26% of the curriculum for pedagogy, anthropology psychology and sociology, 135 credits of Subject Education and educational labs (44% of the curriculum), Apprenticeship organized in cooperation between school and university (8%) with the support of teacher, who are working part time (50%) in university. In the last years more attention is paid in the Apprenticeship and in its relationship between the labs and different subject education.

Physics education and Lab is a specific course of 8+1 credits: this is a value, but value produces the problem on how to perform that course.

Let us reflect on the scientific education in primary school and the relative Teacher education.

Teacher education for scientific primary education is a new challenge which involves the possibility to transfer to the future generations a culture in which science is an integral part, not a marginal one, it involves the possibility to give students the fundamental elements of scientific education that allows the students to manage them in games, in the curious questions, in moments of organized analysis. It is a new challenge with respect to the open social goals of primary education of the past. This challenge implies that pupils become aware of what means an evidence based assertion and how to perform a scientific methodological goal, learning in the same time a social behaviour in sharing ideas and discussing hypothesis. Scientific education has to offer the opportunity to grow the scientific way of thinking and to gradually understand how physics look to the phenomena with respect to the other sciences, i.e. biology. This means for pupils to transform the simple collection of observations in interpretative ideas and to develop formal thinking (Michellini M 2010). The integrated and interdisciplinary approach in primary requires a gradual gain of the subject identity and an attention to the pupils' ideas to produce the conceptual change from common sense ideas to the scientific one (Vosniadou S 2008; Amin T G et al 2014).

Physics Education Research (PER) in fact gives us evidence on how pupils orient observation having an interpretative idea, often implicit, and how for scientific learning is important to help them to explicit ideas and to share interpretative hypothesis⁴. We have to change the teaching style based on the showing phenomena, asking pupils only to observe to collect experiences in the promotion of the scientific reasoning and inquiry approach for explanations and interpretations in the context of Conceptual Labs of Operative Exploration (CLOE) (Michellini M 2006; Michellini M et al 2016).

In-service teachers are not prepared for this goal and they cannot count on supporting materials, because there is a lack of teaching qualified resources for primary school in scientific field. Textbooks for children are informative and often confuse the concepts.

The actual lack of interest on physics is due to the illiteracy of citizen in scientific field⁵: physics would be more appreciated if pupils start studying it early, avoiding to present it only by 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. This is a challenge for all the European universities (Michellini M,

³ In 2000 starts the 4 year long degree and in 2011 it was transformed in 5 year long including competences for disability.

⁴ A large amount of contributions on the interpretative ideas of children can be found in the proceedings of Early Science section of ESERA 2015, 2017 conference.

⁵ PISA project results are showing a substantial scientific illiteracy at all levels

Sperandeo RM 2014). PER have to support the transition phase from the actual information base teaching style in an inquiry based scientific learning style.

Pre-service teacher education have to find a way to offer to the new generation of teachers the competences to profit of curiosity and spontaneous questions of children to build scientific thinking in an interactive way educating children to be active learner responsible.

Relevant problems to solve for such a challenge are: 1) The lack of Prospective Primary Teacher (PPT) competencies on the subject (CK). 2) The difficulties of novices in putting in practice pedagogical knowledge (PK) in relationship with an appropriate CK. 3) The general difficulty to integrate PK and CK for the Pedagogical Content Knowledge (PCK) development (Shulman 1987). 4) Competence in the construction of coherent teaching/learning paths (Michellini M, Sperandeo RM 2014).

The Italian *Physics Education and Lab* course for PPT offer the opportunity to study how to build integrated competences in the subject matter and in the pedagogic aspects for the professional didactic competences, particularly those professional skills related to the use of strategies in context, aimed at helping children overcome conceptual knots and/or activate interpretative models fostering scientific thinking (Elbaz F 1983); Michellini M 2001; Borko H 2004; Abell S 2007; Berger H et al 2008; Davis A and Smithey J 2009).

The basic choice done by us in Udine Research Unit is the integration of Metacultural, Experiential and Situated formative models in the MES model for TEiP (Michellini M, 2004; Michellini M, Santi L, Stefanel A 2013) and to focus on the construction of a flexible Pedagogical Content Knowledge (PCK), based on Physics Education Research (PER).

Figure 1 show how in MES model the CK includes the discussion of Subject Matter and nature of science (NOS), integrated in educational proposals taken by PER literature and how different proposals on the same topic are discussed on the light of learning difficulties emerging by PER researches. The PK part linked by CK includes the discussion of some crucial aspects as the role of operative behaviour or of representations or metaphors in scientific learning and the interplay of math and Physics, in carrying out an analysis of the proposal from didactic point of view (rationale, materials choices, strategies, methods, lab activities, ... metacultural aspects), living by means of tutorials the same experience of children in the conceptual path steps (experiential aspect) and, after a planning experience, a situated learning experience working with children.

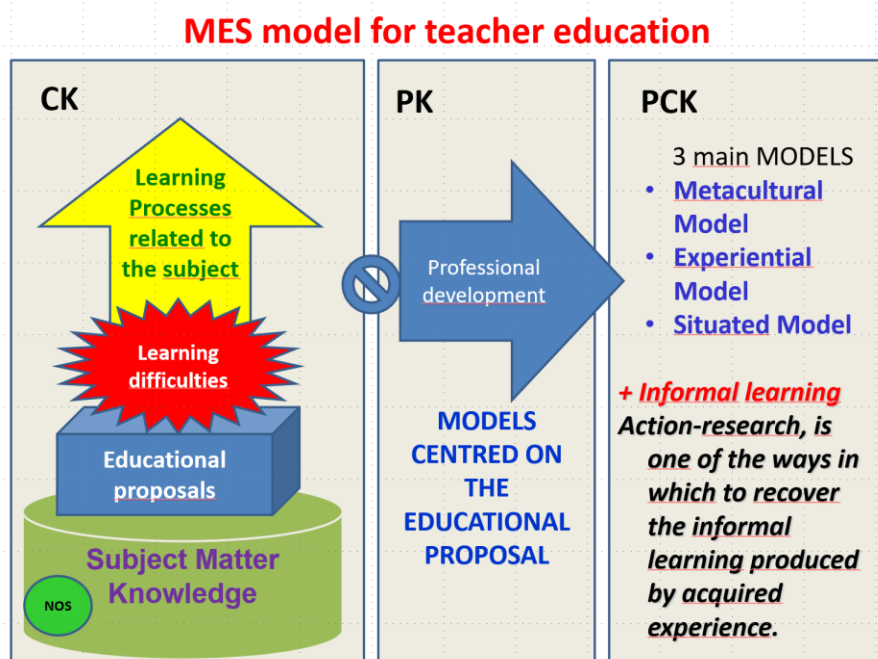


Figure 1 – The MES model for teacher education integrating metacultural, experiential and situated models in developing PCK.

The theoretical framework adopted for the research is the Model of Educational Reconstruction (MER) (Duit R et al 2005). The following five activities characterize the path planning and its implementation in class by PPTs: 1) conceptual reconstruction of subject matter, 2) analysis of main conceptual difficulties of specific topic, 3) analysis of research-based educational proposals, 4) reflection on how main conceptual activities

are dealt with in proposed paths, 5) group discussion about approaches, strategies, activities, instruments and methods as suggested in explored proposals. Inquiry Based Learning (IBL), Prevision-Experimentation-Comparison (PEC) and Conceptual Labs of Operative Exploration (CLOE) strategies are often discussed (Fedele B et al 2005; Michelini M, Stefanel A 2016). Are relevant for PPT education: the personal involvement of PPTs in analysing educational proposals for primary schools, in planning and revising the plan after peer discussion and large group discussion with the responsible of the course and practical classroom implementation of the developed proposals, as emerged by different research based implementation (Michelini M 2003; Corni F et al 2004; Testa I et al 2007; Michelini M et al 2011; Leto F et al 2014; Michelini M, Mossenta A 2014; Michelini M, Santi L, Stefanel A 2014; Vercellati S et al 2014; Michelini M, Vidic E 2016; Vidic E et al 2020).

Secondary School Teacher Education in physics

Eurydice (1998; 2003) offers a rich amount of information on *The teaching profession in Europe*. Several EU funded projects have addressed such main problems of secondary school 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. The inquiries done evidenced the need of research work and of support for teacher education in physics for professional development of in-service teachers as well as pre-service teacher education.

TIMSS Advanced (2008-2010) in particular⁶ found that the book is still the main educational tool used by teachers, in about 100% of the surveyed countries, in more than 50% of the school time the students read “theory” or how to do exercises. The demonstrations of experiments ex-cathedra range from 11 to 54 %. Experiments or investigations done by students range from 0 to 30 % and use of computers range from 0 to 50 % (Sassi E et al 2014).

The main problems in teacher education evidenced in GIREP Workshop held in Reims GIREP-ICPE-MPTL Conference (2010) are related to strategies and methods to develop Pedagogical Content Knowledge (PCK) (Shulman 1987) both in preservice and in-service teacher education (Park, 2008; Michelini M, Sperandeo RM 2014). The Step two EU project⁷ questionnaires results, discussed in Reims, show that in many Countries there are new developments in Teacher Formation Programs and/or Methods and two main models for pre-service teacher education are adopted: sequential or parallel disciplinary and pedagogical education, but from the research results about the nature and level of pre-service physics teacher knowledge emerge that Subject-matter understanding delivered during pre-service teacher education courses is not those conceptual understanding that pre-service teacher will need to develop in their future students. Literature on PCK documented different approaches and instruments (tests, video) on measuring teachers’ PCK, PCK-in-action and PCK-on-action (reflective component of teachers) and developing a models of professional actions competences. Some of the main problems emerging are: a) the lack of competencies in conceptual Science Matter Knowledge (SMK); the need of teachers to gain ownership in the concepts and the ways in which physic interpret phenomena scientific knowledge and natural reasoning often co-exist within the same terrain; b) the tendency to reinforce the spontaneous ideas and local visions of common sense: the general difficulty to integrate PK and SMK for the construction of PCK; c) Adoption of a transmissivity style of teaching notions instead of starting from students’ ideas to develop their reasoning; teaching style reproduce the narrative listing of notions: answers to questions not posed; student common sense reasoning is evocating as educational strategy to involve students, but it is not used as starting point to produce evolution of students’ way of thinking and local to global interpretative perspective is not promoted; d) Lack of coherence in Teaching/Learning paths (Michelini M, Sperandeo RM 2014). Some good practices were discussed in Reims (Aiello et als., 2001; Sperandeo-Mineo et als., 2006; Michelini M 2006; Michelini M et al 2008; Bozzo et al 2010). In this framework, the professional preparation of a science teacher has been deeply analyzed in terms

⁶ 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.

⁷ Steps Two EU Project involved 74 Physics Departments from 32 countries and was supported by EPS had a specific Working Group (WG3) on Physics Teacher Education. <http://www.stepstwo.eu/>

of *professional profile* in the context of jobs for “Human Talent Management” *competences* (Tigelaar et al., 2004).

Steps-Two EU Project produced another important contribution to the TEiP with the Document *European Benchmarks for Physics Teacher Education Degrees*, presented in the World Conference on Physics Education, Istanbul, July 2012 by Urbaan Titulaer⁸ (Tasar F 2012). In that Document the Central Requirement for PTE Education should be: academic, preferably on Master level; research based in the three components: Physics, Didactic of Physics (Teaching/Learning) and Applied Pedagogy and social aspects, containing initial practical training in schools Thesis on T/L activities. Example: Physics Teaching Competencies are: 1) making clear what Science and Physics are, promoting scientific literacy and a disposition for inquiry and further learning; 2) Offer Physics to the pupils, using multiple representations and bridging with pupils’ daily experiences; 3) Designing a T/L plan within the given constraints; 4) Implementing this plan, choosing and designing course material, evaluating their efficacy and learning from experiences made; 5) Knowledge of and experience with a broad spectrum of teaching methods, including school experiments and the use of multimedia; 6) Individuating students’ conceptual difficulties and organizing learning environments for its overcoming.

Recently the Hope EU Project published its results (2017)⁹, which include an inquiry on teacher education analyzed by the Working Group 4. The last activity of the HOPE project was a Forum held in Constanta, Romania on September 2016 on teachers’ needs with the participation of the representatives of the 71 project partners. In the conclusions it was underlined that the relevant aspects that need research are: 1) how to test PCK (instruments and methods); 2) how to promote methodological competencies related to experimental exploration, modeling and building formal thinking; 3) How to promote argumentation in discourse, description vs interpretation in phenomena exploration and representation role in promoting learning. In the general conclusions the recommendations sent to the EU Community were: A) School-university cooperation in Teacher Education and innovation on teaching/learning have to be promoted and supported; B) PER includes applied research activities and have to be integrated in Teacher Education and in classroom praxis; C) Ministry of education in EU have to agree on goals and learning outcomes – standards and guidelines, assuming the responsibility to apply the shared principle in the autonomy of the different contexts. We hope that EU promote a Task Force on Teacher Education, as those in USA¹⁰ to support the PER research in that field and to transform in guidelines the PER results and good examples developed up to now.

The Dialogue 1 initiative and questions on primary, secondary and university pre-service teacher education

A lot of work (research and experiences) on Teacher Education is now available in all Countries in the World. We, as GIREP community, have to collect needs and results, promoting research and intervention modules in that field. Inspired by this idea Jenaro Guisasola, Kristina Zuza and me organized the *Dialogue 1 on Primary, Secondary and University pre-service physics teacher Education* with two preparing actions. The first action was to prepare and ask 6 questions in advance on this problem to the participants to the San Sebastian Conference, collecting and summarizing results. The second action was to invite experts (Knut NEUMANN¹¹, Gabriela LORENZO¹², Laurence Viennot¹³) coming from very different research approach to offer with me an overview of the problem from their perspective, thinking to the same questions and considering the summarized additional questions posed by participants. By means of this preparation we offer to the participants the opportunity to have a real role in a plenary session.

⁸ Task force members for the document presented are: Ovidiu Caltun, Iasi, RO; Eamonn Cunningham, Dublin, IE; Gerrit Kuik and Ed van den Berg, Amsterdam, NE; Marisa Michelini, Udine, IT; Gorazd Planinsic, Ljubljana, SI; Elena Sassi, Napoli, IT; Urbaan Titulaer, Linz, AT (Chair); Rita van Peteghem, Antwerpen, BE; Frank van Steenwijk, Groningen, NL; Vaggelis Vitoratos, Patras, GR.

⁹ HOPE EU Project is an LLP network project involving 71 Universities. www.hope.org

¹⁰ National Task Force on Teacher Education in Physics (NTFTPEP, USA) <http://www.ptec.org/taskforce>

¹¹ from Leibniz-Institute for Science and Mathematics Education (IPN) at the University of Kiel, Germany

¹² Universidad de Buenos Aires, Facultad de Farmacia y Bioquímica - Consejo Nacional de Investigaciones Científicas y Técnicas in Argentina

¹³ and Nicolas D’ecamp, Laboratoire de Didactique Andr e Revuz, EA 4434, Universit e Paris Diderot, Paris, France

Table 1 report the 6 question posed by us and Figure 2 show the grouped distribution of the 115 questions posed by participants.

Let us exemplify the questions posed.

Some questions are very general, as the following

1. Do we really want to develop critical thinking in teachers, and how to proceed in this regard?
2. How does one ensure that a solid Physics training stays central to the preparation of a teacher in this technological world?
3. How should a physics teacher take into account a growing multidisciplinary world?
4. If we have not to improve the scientific education/curriculum because it is good enough, can we be more selective in the capacitation process of physics teachers?
5. In Brazil, the best students do not want to become science teachers. What initiatives can reverse this situation in a developing country where the teaching career is so undervalued?
6. In which way could being part of a science educational research team influence on the professional teacher development?
7. Is it desirable to have educated scientists as teachers in primary and secondary education?
8. What is the role of physics departments in the preparation of Physics teachers?
9. What is the situation about the university physics teachers' training?
10. What kind of training/knowledge (if any) should a physics teachers' educator have?
11. Which examples of new technology are suited for teacher education?
12. What pedagogical content knowledge needs a good physics teacher?
13. Why the history of science is still more factual rather than processual and epistemological in teachers preparation?
14. How can we support teachers to teach concepts of quantum physics?

The 24% of questions are relative to ICT and technologies. Examples of the main questions posed are the following.

1. Wouldn't it be more interesting to put **technological knowledge into practice** in the classroom?
2. Do we need **professional development** for in-service teacher that **treats how devices that students know from everyday life** such as refrigerators etc. work?
3. Does the **university research considers the technological conditions** at school?
4. From which new technological techniques would you take **advantage to teach complex concepts such as Quantum Mechanics**?
5. How big, in your opinion, is the risk to hide a lack in educational meaning behind technology?
6. **How can robotics and programming be used for integrated STEM education?**
7. How engaging are these activities (related to technology) for physics students?
8. **How important is it for teachers to recognize the technological implications** of the basic physics they teach?
9. What are **best practice examples of integrating technology into teacher education**?

Strategies and methods (12%) is the second questions' area for relevance. Example of the main questions are the following.

1. How can prospective teachers apply the knowledge on **alternative conceptions** of heat and temperature in their teaching proposal?
2. In physics education, Is a **Learning Cycle a good strategy** of teaching to improve the understanding of students?
3. What are an efficient approach to an astronomical observation for a lay audience?
4. What are the best learning **approaches** to teach physics in **high number students' groups**?
5. What strategies can I use to **involve** my students more during the classes?
6. How do we encourage **sense-making** if we reward only the correct canonical answer?
7. On the basis of what basic contents is it possible to articulate the degree of scientist and the subsequent teaching so that, when teaching, the teaching of science will be oriented towards inquiry based on models?

Table 1 Questions posed to the participants and to the experts in Dialogue 1

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1. We have three different teacher profiles: primary teachers, secondary school teachers and university teachers. From your research evidence,

- a. Which are the main problems for each profile? How do you find solutions?
 - b. what sort of activities in teacher education do promote their professional competencies? How?
 - c. How can the different competencies needed by teachers in the different levels considered be integrated?
 2. How can prospective teachers find opportunities to develop the main professional skills
 - a. Which is the role of psychological -pedagogical education?
 - b. How can be discussed the contents for teaching conceptual competences?
 - c. Which kind of lab emerge to be useful?
 - d. How to conduct apprenticeship?
 3. How can be prepared physics teacher for a significant integration of:
 - a. ICT in school activities?
 - b. Lab work in school activities?
 4. How to integrate physics education research in physics teacher education?
 5. How can physics teaching competence be evaluate?
 6. How can we carry out research on teacher education now?
-

Systems needed for teacher education and role of institutions produce 10% of questions, reproducing the spectra of research questions we found in the mentioned EU inquiries.

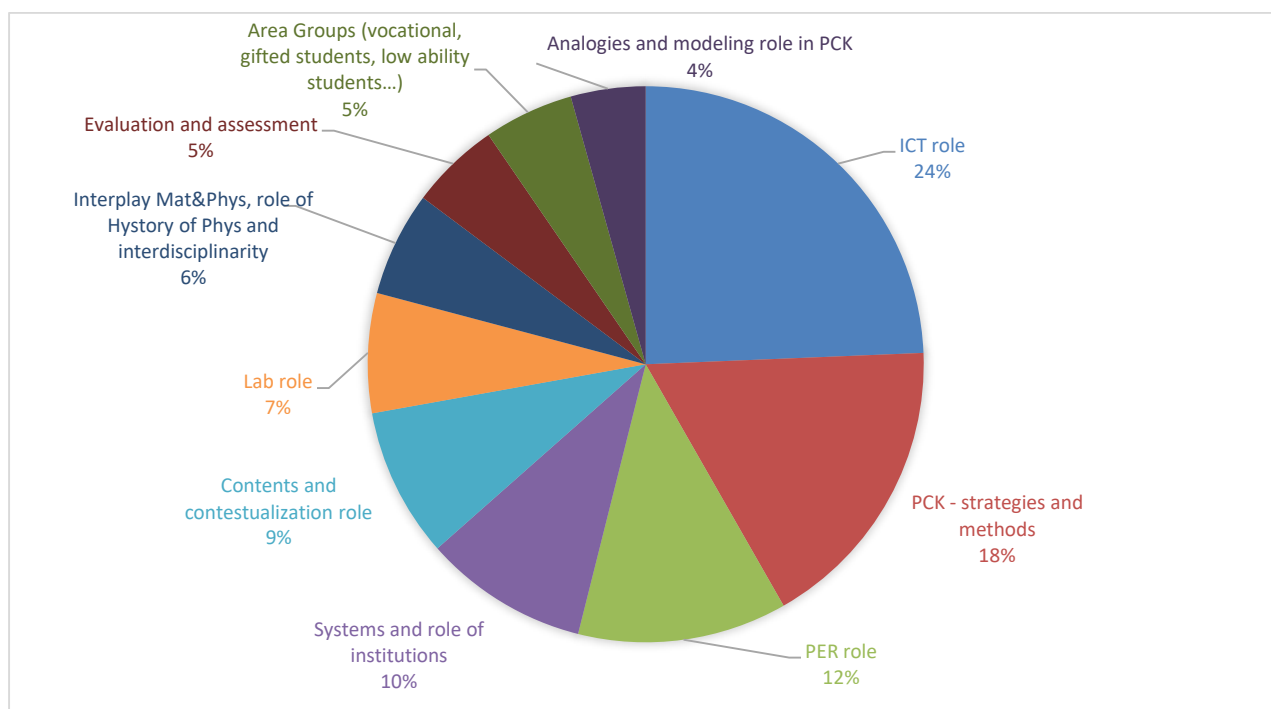
Contents and contextualization in learning collect 10% of questions, as the following

1. Is it really necessary to cover the amount of content that today is taught in secondary education?
2. How can we use Cosmology context to teach advanced physics topics?
3. Is it helpful to start with concrete context like light bulb when teaching Electricity?
4. To what extent can a teaching/learning sequence about spectra foster students' understanding of waves?
5. What contributions can the use of PSTU give to the teaching of Cosmology?
6. How can we build on chemistry knowledge to introduce basic quantum mechanics concepts?

Teaching specific contents is another area of questions.

1. What are the challenges in teaching Einsteinian Physics at upper secondary school level?
2. What is the common order of teaching the concepts of force and momentum in your country? Do you agree with it, and why?
3. What is your experiences about the teaching of electromagnetic induction at secondary school?
4. What makes the learning domain of general relativity challenging?
5. What should physics teachers know about entanglement?
6. Is it possible to introduce summative lectures that frame mechanics contents in discipline-culture framework?

Figure 2 – The grouped distribution of 115 questions posed by participants



The lab role activate the 7% of questions as the following

1. Do you think lab practices foster significant learning?
2. In classes that involve concepts of modern and contemporary physics do teachers use more **experimental activities or just phenomenological descriptions?**
3. What are the students views regarding the implementation of online science laboratory work and what are the theoretical grounds of this method?
4. What is the role of lab activities to enhance students' interpretation of visual representations in physics?
5. **Which experiment skills are required on Physics ENEM items?**

The other categories of Fig.2 are self-explaining.

The following questions on research and education are particularly motivated.

1. To what degree should we require that new teachers/university faculty become familiar with the current state of education research before starting their professional practice?
2. What is the correct relationship between mentoring and research?
3. Which test was used for your research?

Very few are the questions posed for primary scientific education: only two, asking if and how energy can be treated in primary and asking for good practices in general.

Questions on university teacher education are few, but interesting, as the following.

1. Is it recommended to have a research background to lecture Physics at University level?
2. What common problems do engineering students encounter with physics assignments in the first year?
3. For new faculty in universities, who presumably have extensive research experience, what specific training or preparation in pedagogy is offered to bring them up to speed in that regard?
4. Physics education means also preparing new researchers in Physics. Most of researchers nowadays have to write code to perform analyses. How much that should be embedded in the Physics curricula?

Questions announced as focused on pre-service teacher education are very spread, as the following examples indicate.

1. How and how much statistics do students learn to become physics teacher?
2. How can we teach pre-service teachers to incorporate new learning strategies into practical assignments in the classroom?
3. How can we teach pre-service teachers to use contextualized experiences in the classroom?
4. How can we train students better in pre-service teacher education to initiate and moderate/lead discussions among scholars about problems in physics?

5. How do we encourage didactical reconstruction by trainees?
6. How do we train prospective teachers to inspire and motivate their students?
7. Which interdisciplinary science ideas do pre-service teachers need to know?
8. How sort of aspects of theoretical physics/mathematical physics are relevant for those who become a teacher compared to those who become a physicist?
9. Which is the role of practical work in pre-service teacher education?
10. Which strategy does work best to improve PCK in physics regarding generalist pre-service primary teachers?
11. Do pre-service teachers have a strong sense of agency at the start of the course?

The 115 question posed and their organization here described were sent to the expert for their contributions reported here in the following.

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