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Answering to physics teachers' needs in professional development

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Answering to physics teachers' needs in professional development

D Buongiorno[1,a], M Michelini[1,b], L Santi[1,c] and A Stefanel[1,d]
[1] *Physics Education Research Unit, University of Udine, via delle Scienze 206, 33100 Udine, Italy*
[a] *email: buongiornodaniele@gmail.com*
[b] *email: marisa.michelini@uniud.it*
[c] *email: lorenzo.santi@uniud.it*
[d] *email corresponding author: alberto.stefanel@uniud.it*

Abstract. The IDIFO project conducted at the University of Udine, in collaboration with 18 Italian universities, is an example of integration and collaboration between schools and universities proposals on innovation in physics education. The aspects of the project relating to the professional development of teachers are discussed, presenting the various implementation methods designed and activated, also answering to the formative needs of schools relating to laboratory-based scientific teaching/learning.

1. Introduction

Professional teacher development is an issue which has been given great attention by Institutions [1] and research communities [2-9]. The integration of knowledge [10], sources and practices [11], their contextualization [12] to build skills and not just knowledge bases in the PCK-Pedagogical Content Knowledge [13] are the basis of the teachers' professional development research outcomes. As in other European countries, the professional development of Italian in-service teachers was not structured and, therefore, has been implemented in different ways and isolated projects [14], which despite being in many cases of quality, have not been included in a coherent and stable institutional network. An important contribution was given by the Scientific Degree National Plan (PLS) [15], a nationally coordinated project since 2005 for the promotion of scientific culture in the connection between school and university. In the limit of the PLS plan, the Physics Education Research Unit (PERU) of the University of Udine promoted the project IDIFO (Didactic Innovation in Physics and Guidance) [16-17]. In this context different kinds of research based teacher professional development were studied and implemented as a feedback at the school requests. This research work is presented here.

2. Research questions

The aim of this contribution is to give an overview of different formative strategies and methods for teachers' professional development, in particular focusing on the following questions:
Q1. What strategies are being used for physics teacher professional learning and what are the strengths/weakness of these strategies?
Q2. What are the key aims, elements and methods used to support physics teacher professional learning?
Q3. How are physics teachers' needs identified and addressed in professional learning opportunities?

3. The characteristics of the PLS layout and of the project IDIFO

The IDIFO project, born in 2006 and still active now, is the contribution to PLS of the Italian research community in physics education made up of 18 cooperating national universities coordinated by the Udine PERU (Fig. 1). It promotes in PLS the research dimension, both in national coordinated actions and in local ones, the cooperation and the peer comparison between network partners. The main in-service teacher professional development common action is a biannual Master offering more than 160 cts organized in 2 cts modules that teachers can chose for their professional profile of 60 cts Master, or for 15 cts annual advanced course, or for a 2cts modules on the area of modern physics, physics in contexts, RTL and modelling, formative guidance, action research [18], as illustrate in the fig.1. The following lists the main qualifying aspects [16-17, 19-28]:

a) Physics Education Research [8-9, 11-13, 18, 29-35] was the reference framework for professional development strategies, contents, resources [10, 16-17,19-21, 34], available also online [36-38];

b) Integration of formative activities, design phases, experimentations in school monitoring and analyzing the learning processes with research instruments, producing new didactic materials and reflection on action [10-12, 31, 33];

c) Analysis and discussion of different approaches for the same topic, as for example four approaches on Quantum Mechanics developed by Italian research groups [16-17, 19-21];

d) Inclusion of transversal issues and activities in the field of physics, guidance, problem solving, physics education research methodologies [16, 19, 27];

e) Biannual structure of the Master giving the opportunity of the building personal formative profiles promoting an effective integration between the university formation and the school life [17, 19, 24];

f) The formative offer including Modules in presence and other on-line with a-synchronous and synchronous modality and in addition full immersion summer week in presence [17, 19-20, 23, 25].

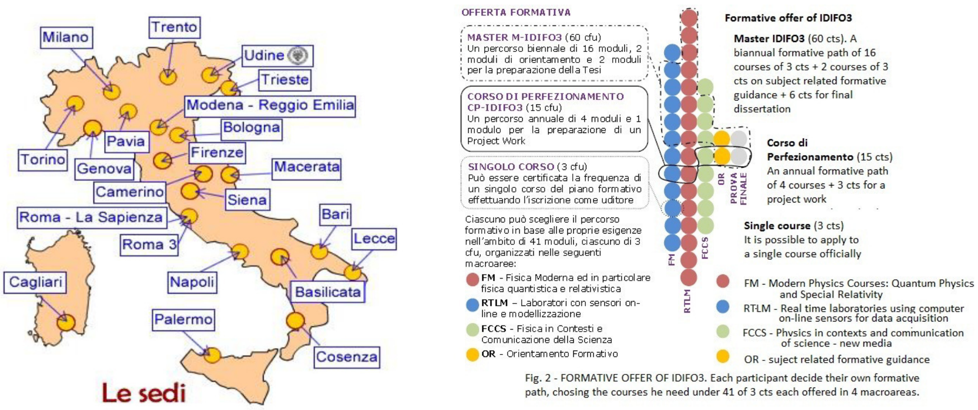

Figure 1. The map of Italy evidencing the sites of the University collaborating to the IDIFO project through their physics education research group.

In the framework of the Master of the IDIFO project, different actions were studied and implemented for teachers' professional development, answering to the requests emerging from schools as formative needs and valuing in a different way the main characteristics of the Master, summarized above in points a) to f). These actions involved about 150 in service physics teachers per years (from 2006 till now) of high schools of all Italy. Two-thirds have a degree in mathematics, just under a third a degree in physics and the remainder have engineering degrees. In the next section 4 we discuss the main issues charactering the different actions and their role in teacher formation.

4. The characteristics of the laboratories offered for teacher formation and monitoring tools

Often, as a relapse of inquiry activities carried out with secondary students in lab of the IDIFO project of the PLS, the PERU was requested for teacher professional development by single schools or schools network, local community of teachers' associations as AIF [39-40] or SISFA [41-43]. The needs of teachers emerge in school-university collaboration in which the university puts in place proposals for research based didactic innovation, the school chooses among the proposals offered, contributing to modify them according to its needs and requesting new interventions, initially almost always of content and then also on strategies, which are defined and shared in research-teachers' meetings (in presence or at a distance). These meetings were organized in agreement between researchers and teachers in 1-3 hours, depending on the case, on different aspects:

- to define contents to be addressed (for example including connection with school curricula, analysis of exercises, critical analysis of textbooks) and strategies to be adopted
- how to implement and set up the activities (e.g. presentation of innovative paths following a metacultural model [10, 35]; experiential labs [10-12, 35] to innovative proposals conducted with tutorials, questionnaires, exploratory experimental laboratory activities [19, 31, 33-35]; design, experimentation in context [12, 19, 25, 32] and analysis of students' learning paths, their difficulties [13, 18, 20, 30].
- to establish duration and calendar of formative interventions (e.g. interventions divided into 3-4 meetings of 3-4 hours each, per week, always with at least one preparatory meeting and one final summary meeting (generally scheduled towards the end of the school year).

This merge of school and university contributions produced different educational laboratories in which researchers and teachers collaborate to create learning environments of practitioners. The formative needs of teachers merge with research-based teaching innovation, implemented according to the approach of Duit's MER [30]. In our research approach on teacher professional development [10, 19, 25], the analysis of innovative research-based pathways forms the CKs of teachers. The analysis and reflection on disciplinary issues produces PCK [9, 35]. planning and experimentation in the classroom transforms this knowledge into acting knowledge [10, 20-21, 35]. All the phases and the different types of formative intervention developed are based on continuous monitoring that allows us to develop dynamics evidence based teacher learning strategies [46-49].

We collected feedback from teachers with the following instruments and methods [16-17, 20, 26, 28, 44, 50-56]. For each activity attended, the trainee teachers filled a questionnaire in which they were asked to indicate a score from 1 to 5 (1: insufficient; 2 sufficient; 3 good; 4 very good; 5 excellent) on the following items: A) Interest aroused; B) Clarity and presentation effectiveness; C) Stimulus for theoretical reflection D) Cultural and personal utility; E) Contribution to teaching professionalism; F) overall evaluation of the activity. Free comments were then requested on the significance, effectiveness and usefulness of content and contribution to their preparation, interest in the activities followed and on the critical elements of each of them. In the laboratories where teachers analyzed educational paths, the tutorials [31] accompanying each path have been used both as work tools and as monitoring tools [21]. PCK questionnaires have also been specially constructed [9-10, 56], with items that include both a CK part (disciplinary knowledge) and a PCK part (teacher knowledge), starting from literature on learning processes. The PCK questionnaires were administered before and after the formative intervention promoting reflection and construction on specific PCKs [13] and giving information on the CK and PCK in formation of teachers [44, 54-56, 61]. In the laboratories including planning and classroom activities with related documentation, the materials produced by the trainees' teachers also became monitoring tools from which the formative outcomes were collected concerning different indicators such as didactic strategy adopted, tools used, attention to students, analysis of the conceptual nodes [16, 19-20, 26-28, 33-34, 56] and how to overcome these with students [31, 35].

In the following the characteristic of the main formative laboratories, each of which was framed as a module of 2 cts (equal to no less than 10 hours per cts), in the institutional and scientific framework of the IDIFO master, briefly described in section 3. For each laboratory, role / strength and weaknesses are discussed, supporting the argumentation with only a few summary data, more extensively presented in previous works [10, 16, 19, 20- 28, 45].

4.1. Experimental Laboratory (27% of the total activities carried out)

The Experimental Laboratory [33, 44-45, 51, 54] aims to construct the Phenomenological Laws following the Fourier approach, for example, in the study of thermal interactions. It is based on a series

of experiments aimed at identifying the role of relevant parameters and variables in a phenomenon. From the analysis of the graphs of the temporal evolution of these variables, once the values of the system parameters have been set, regularities and empirical laws are recognized, which describe the phenomenon, stimulating the search for interpretative models [33-34]. Two strategies adopted: (a) Prevision-Exploration / Experiment-Comparison [57] by means of tutorials [31, 56]; (b) approach to open problem solving for formative guidance [58-59, 61-64], analysis of artefact [65], inviting an experimental work design after an initial qualitative exploration of a phenomenology [20, 45-46].
This kind of laboratory was set up for initial teacher formation, for example, on optical diffraction and thermal conduction [10, 51-53, 62]. In more recent time, these labs give answer to groups of teachers from an entire school asked us to work on experiments to master them. The most requested were on: oscillations, thermal phenomena, energy concept, electromagnetic induction, physical optics and spectroscopy, photoelectric and Franck/Hertz experiments, measurement of the speed of light and of ratio e/m for the electron, electrical conduction [44-45, 54, 56, 58-59].

From the questionnaires filled by the trainee teachers, these laboratories achieved an average score of 4.1 out of 5 (minimum score 3.8, maximum score 4.3). A typical free comment highlights value and criticalities of this kind of lab: “The content was interesting, but time was too limited for richness of topics covered". The analysis of teachers’ feedback collected from the questionnaires and free comments [19-25] shows the role of this laboratory in promoting IBL [31, 59] laboratory-based didactic focused on the resolution of real experimental problems and not simple checks of already known laws, valorizing both traditional instrumentation (sometimes unused although available in schools) and computer or smartphone based data acquisition. Finally, it allows schools to support the use of the laboratory, both where they do not have one, and where it is underused or not used, and where it is not used effectively. There are three main issues to be solved to ensure the effectiveness of this laboratory: teacher time both to appropriate the experiments, to implement them in schools, to manage them effectively with students; the change of perspective needed, toward a didactic experimental laboratory reproducing a research environment in which real interpretative problems are posed and where the student is required to actively contribute right from the design of the experiment. Table 1 gives a summary of strength and weakness of this lab.

Table 1. Role/strength and weakness of the Experimental Laboratory for the Construction of Phenomenological Laws.

Role/strength	Weakness
inquiry based learning in the experimental lab	too many hours of training to truly master the experiments…
for experiments on traditional topics, but also especially on modern physics	…and methodology
promote experiment based physics education and support school for experimental lab	the conditions for carrying out experimental laboratories are not always available in schools.

4.2. Paths Laboratory (31%)
In a path laboratory the teachers in formation face innovative research-based educational paths [10, 16, 19-28, 35, 40, 44-45, 50-53], merging a metacultural modality and an experiential one [23, 35, 66-72]. The presentation of the didactic path carried out with a metacultural modality provides the trainee teachers with a complete view on the didactic path that is proposed to them. The analysis of the tutorials that are an integral part of the didactic proposal, carried out with an experiential modality, both individually and in small groups and then resumed in a large group makes them live an experience similar to that which their students will experience when they face the path in class. The combination of the two modalities provides teachers with mastery of the single key steps of the educational path, without losing sight of the logical coherence of the development of the entire path. This kind of lab was offered concerning: electrical phenomena [56, 58], electromagnetism and superconductivity [21, 65, 67, 71], optics [51], thermal phenomena [52-53], modern physics proposals for a global vision [21, 46, 9-40,

46], quantum mechanics [26-28, 64], mass-energy and relativistic dynamics [74-75], optical spectroscopy [76], RBS and gamma spectroscopy [77-78].

The average evaluation of these laboratories was 4.4-4.5/5, with maximum peaks of 4.8/5 and minimum evaluations never lower than 4.1/5. The aspects that obtained the highest evaluations were the acquisition of innovative teaching methodologies (score 4.8/5) and cultural enrichment of the contents (score 4.5/5), motivated by comments such as: “I found it very useful for my cultural education", "The course provided useful information for teaching and clarified important aspects of the contents [the list of specific contents learned follows]”, “Access to tools and methodologies not available at the school”. From the PCK questionnaires and the didactic projects designed by the trainees teachers it was possible to identify the main role of this type of laboratory [24, 28, 51, 66]: to promote research-based educational innovation in schools, both at the content level (more traditional but still current for physical research and above all linked to modern physics) and at a methodological level (promoting IBL, problem solving, analysis of artefact approaches, use of tools and methodologies typical of research both to monitor learning and to analyze it. This type of laboratory is the ideal context to enable trainee teachers to become researchers themselves in carrying out action research activities. The papers produced by the teachers themselves constitute one of the most relevant evidences of the role of these labs for professional development [56, 65, 77, 79].

Table 2. Role/strength and weakness of the path laboratory.

Role/strengths	Weakness
Support school for innovation on topics and method (in particular on T/L modern physics) Inquiry based learning strategies Monitoring tools based on research Problems and exercises Activity of action-research	Too time spending activity for school teachers Need of continuous actions Too many innovative elements, often frightened teachers who were less inclined to innovation The surprisingly positive students learning paths, are sometimes far from the demands traditionally made in final state exams Need to experienced how we propose the activity directly to their students

4.3. Testimonies Laboratory (22%)

In the limit of the IDIFO project, we were asked to work with groups of students for innovative research based educational paths on the topics listed above. The teachers actively collaborated in the preparation of the students and in the monitoring of their learning both during the activity conducted by the researchers and afterwards at school. The analysis of the monitoring results was discussed in afternoon meetings jointly by teachers and researchers. These testimonies labs were combined with the previous and obtained average scores very high: 4.9 / 5 is the average of the ratings assigned overall, with positive peaks for "Access to tools and methodologies not available at school" (4.9 / 5), Innovation of teaching methods (4/5), expansion of disciplinary knowledge (4.5 / 5), the connection with the contents taught at school in physics and in other disciplines (4/5), the didactic ideas received (4.2 / 5). Some comments give a look at the reasons: "connection to the curricular paths typically done at school, constituting an enrichment and insight very useful for both students and me", "Observing non-reproducible phenomena at school", "having the presentations used, to use them in the classroom”, “Links with other disciplines: mathematics, chemistry, earth sciences”.

Table 3. Role/strength and weakness of the Testimonies Laboratory.

Role/strengths	Weakness
Teachers have experience of **- how to interact with students by giving them an active role, how to implement active learning environments** **- how to monitor student's learning paths**	**Some teachers tend to delegate the conduct of teaching to the researcher, without appropriating innovative contents and methods (because they are considered too complex and difficult, not sufficiently mastered).**
- how to use research methods to analyze these paths	**difficulty in transferring the methodologies used to other areas**

These labs offer examples to teachers, on how to face students' topics often considered too difficult for students (as for instance quantum physics or contents of special relativity), or too far from the teacher university formation (the topics of modern physics). This lab also provides to teachers a picture of the typical student responses and their reactions that often surprise teachers themselves: students less motivated by traditional teaching approaches often respond in a meaningful way when they face an active learning approach based on intellectual challenges, in particular dealing with interesting topics such as those of modern physics. There are two main weaknesses of this type of laboratory: some teachers tend to delegate the conduct of teaching to the researcher, without appropriating innovative contents and methods (because they are considered too complex and difficult, not sufficiently mastered); the methodology experienced in the lab on a specific topic are not automatically transferable to other topics without adequate formation [21-22, 24, 55].

4.4. Curricular Planning Laboratory (9%)
In this type of laboratory, teachers plan an educational path and the accompanying didactic tools (tutorials, pre / post tests, exercises, support materials ...) in view of an effective experimentation in a class [29-30]. This type of laboratory constitutes an essential element in teacher preparation both because the acquisition of an innovative research-based path effectively becomes its patrimony, and because in this way the teachers acquire basic competencies that are part of the teaching professionalism. The topics proposed in this lab coincide with those of the previous labs, with which they are evidently intertwined. However, it is important to point out that in this type of laboratory the teacher effectively becomes the master of a didactic proposal, transforms it to adapt it to his own teaching style, to his own skills, while maintaining the coherence and logic of the path that has been designed and implemented. developed by others. In our experience this kind of lab was adopted with associated schools asking us to work together for two years to design an organic vertical path of physics, having as a reference didactic research for innovation [9, 12, 33-35] and involving all physics teachers.

Table 4. Role/strength and weakness of the Curricular Planning Laboratory.

Role/strengths	Weakness
Strong collaboration school-university Activity of action-research	The process requires an active and driving role of one or more referring teachers who act as promoters and of the principal who must endorse the action and support it
Improving the quality of teachers and of physics teaching/learning	Some teachers are refractory to didactic innovation

This type of laboratory is carried out where there are the conditions to create a strong collaboration between school and university, requiring a great commitment on the part of teachers to adopt innovative methodologies and approaches, the presence of a teacher who acts as a reference for the school, the availability of the school as an institution and of its principal so that the participation of teachers in formative activities is encouraged and organized, even during curricular hours. In addition to the maximum evaluation attributed to this type of laboratory (4.9/5), from teacher educational projects, from the documentation of experimentation in school and from the PCK questionnaires, emerged effectiveness and value of this laboratory: the continuity of the collaboration over the years; the didactic projects developed and experimented by the teachers; the papers that the teachers themselves have produced to document the projects and activities carried out with their students [28, 56, 68].

4.5. School-work alternation Laboratory (11%)

In the latest reforms of the high school in Italy, compulsory formative activities for alternating school work and orientation have been included, which each school had to organize autonomously, coordinating with the work world and other external institution (as University). In response to the pressing demands of schools for this new commitment, we designed collaborative work with teachers, in which the university proposes itself as an employer for students. The request to the students was to identify APPs in a thematic area, such as mechanics, sound, optics, spectroscopy, to be developed, making a study of characteristics to help students' understanding of physics. The teachers become school tutors of their own students supporting them as an expert resource in setting up the experiments, but above all constituting an irreplaceable trade union between students, the school as an institution, the researcher who conducted the laboratory, the university as an institution that offers a work experience to school students. Moreover, this type of laboratory requires a strong collaboration between school and university and a teacher who acts as a contact person, to guarantee an effective institutional connection and to ensure adequate tutoring for students, who would otherwise tend to get lost. This type of laboratory has a great educational value for teachers in providing them with transversal skills related to guidance, collaboration between institutions, contents addressed and experimental methodologies.

Table 5. Role/strength and weakness of the school-work alternation Laboratory.

Role/strengths	Weakness
Support school for experimental lab The smartphone as instruments for experiments Design activity Teacher as researcher	Soft skills request Time spending and onerous activity Some teachers delegated researchers

The publications performed by the teachers on this kind of laboratories, and the other last two, are the main validation feedback and confirmation of effectiveness of this type of laboratories, where one can find documented the quality of the products developed by the students, the outcome of the monitoring of the process implemented by the schools and the impact on the teacher formation [79-83].

5. Conclusion

The professional development of teachers is a topic to which great attention has been paid both at the institutional level and by the world of research but which, in several countries such as Italy, has not found a structured definition. The plan PLS for scientific degrees of the Ministry of Education has made a great contribution to which our research unit has contributed for over 15 years with a national Master for professional development coordinated with 18 Italian universities. In this context, both face-to-face and online formative activities were offered to schools. In our experience of teacher professional development, we encountered explicit requests of schools which became research-based modalities only when the teachers experienced first-hand followed the detailed activity we proposed directly to their students (Q3). Some characteristics of the activities carried out can be assumed as quality conditions to be adopted (Q1-

Q2): the active and collaborative role of the teachers involved; attention to school teaching activities; monitoring of learning and the training needs of educational innovation schools; integration with educational research; the approach that responds to needs and at the same time proposes didactic innovation; the presence of experimental activities. The collaboration of several universities on a national level has raised the level of activities and enriched their contents. Different types of educational laboratories have been studied and developed: laboratories for the appropriation of specific experiments with IBL modality, problem solving, analysis of artefacts; workshops for the discussion and analysis of research-based educational paths; workshops activated by the inquiry activities carried out by us with the students; curriculum planning workshops; workshops linked to the students' work alternation activities. The most relevant results concerned the introduction of educational innovation based on IBL also documented in papers published by the trained teachers. Moreover, they developed skills in didactic planning on the specific physics contents considered and transversal skills in formative guidance and in collaboration between university and school.

6. Authors' ORCID iD

Marisa Michelini, 0000-0003-4764-9774
Lorenzo Santi, 0000-0002-2130-587X
Alberto Stefanel, 0000-0001-9662-0025

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