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An overview of physics teacher professional development activities organized within the Italian PLS-Physics plan over the past five years

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Abstract. The Italian PLS-"Piano Lauree Scientifiche" project has among its objectives the improvement of school-university cooperation, with a special emphasis on in-service teacher professional development. In pursuit of such goal, growing resources and an increasing effort to strengthen the collaboration with schools have been employed in the past years. A working

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group within the physics section of the PLS project has developed a questionnaire to inquire about teacher formation activities organized during the past five years. After extensive revision and testing, the university network of PLS-Physics was asked to fill the questionnaire. The resulting data from 139 initiatives provides an interesting perspective on the kind of activities, organizational choices and educational priorities for teacher professional development within the PLS-physics project.

1. Introduction

The Plan for Science Degrees (*Piano Lauree Scientifiche* - henceforth PLS) is a long-standing University project funded by the Italian Ministry of Education which has among its primary objectives, since its foundation in 2004, the collaboration with high schools and teachers, especially aimed at teacher professional development [1]. More generally, the aims of PLS are related to the development and quality improvement of the Italian educational system, with a focus on science disciplines, under several aspects: besides teacher professional development, direct guidance and counselling of pre-University students, also through laboratories in University, self-evaluation activities, refining of post high-school preparation, favouring of an equal gender balance; reduction of dropout rates in the first years of University; formation of University tutors. PLS is divided into sub-projects, related to different disciplines within the scientific field: the PLS-Physics community, composed of 36 partner universities, includes several groups actively engaged in Physics Education Research (PER), and has a long tradition of adopting innovative strategies in teacher professional development, such as cooperative learning methods, collaborative design of laboratories for students with groups of teachers, and the formation of communities of practice on selected objectives. Over the years, the PLS-Physics community has accumulated a valuable patrimony of experiences in teacher professional development, and has established a network of thousands of schools, with a continuous school-university dialogue which has allowed to intercept the educational needs of teachers, and in many cases to foresee in advance the critical issues which could have been raised by changes in educational policies and curriculum. It has to be mentioned for example that the policies on pre-service teacher education have been quite unstable in Italy during the last 10 years, going through the adoption of four successive, very different models of initial training, with a significant risk of widening the gap between teaching methodologies recommended by PER and actual classroom practices (which is to some extent present in all educational systems [2]). Correspondingly, in the last years PLS-Physics has increased its efforts on in-service teacher professional development, also with specific addressed initiatives aimed at filling gaps in teacher initial training, both in disciplinary topics and teaching methodologies. Overall, the training activities promoted by PLS-Physics involve about a thousand teachers throughout Italy each year, and cover aspects such as the deepening of disciplinary and interdisciplinary topics, results from education research, methodological issues, the use of new technologies (tracker, Arduino, smartphone, etc.), with a special emphasis on the realization of laboratory experiments. Post-degree masters dedicated to teachers, summer schools, regional and national courses have been activated in collaboration between multiple Universities, forming a distributed network of opportunities for professional development to which practically every teacher in Italy has the possibility to get access.

In November 2019, near the end of a cycle of PLS operation, Josette Immè, head of the physics section of PLS, proposed the formation of working groups to report on the results of the various goals of PLS. The working group on in-service teacher education, which comprises all the authors of this contribution, with Marisa Michelini as coordinator, started elaborating a questionnaire to give to representatives of the various Universities participating to PLS-physics, about the activities of teacher education which were realized in the past five years. After extensive revision and internal tests, the questionnaire was finally made open. The questionnaire comprises 46 items asking for several details on the organization, content, goals, intended and actual participants, and required effort from teachers for each course organized by each University. The survey received 139 responses, which considering courses which were repeated over several years correspond to 243 teacher training courses over the last five years; such number should be interpreted as a lower bound estimate of the number of teacher education initiatives realized within PLS-physics in the past five years.

2. Methods

The questionnaire is composed of 46 items, most of which non-exclusive multiple choice. Broadly speaking, items aim at acquiring information on the organizational aspects, the areas of intervention, the objectives, the didactic typology and the skills acquired by the teachers participating in the training activities.

2.1. Organizational aspects

The first part of the questionnaire collects information on organizational aspects of teacher training activities in the various locations. Items concern the logistical aspect of the initiative such as location, the characteristics of formators and attending teachers, and whether the initiative to start the course was taken by the University, the schools, or in concert between the two. This part of the questionnaire also includes information concerning the actual organization of the courses, such as the number of students, number and characteristics of formators, student teacher commitment in terms of hours of attendance, certified hours and costs.

2.2. Areas of intervention

The questionnaire identifies three non-mutually exclusive macro-categories of intervention areas or directions: *specific institutional* areas which serve to position the course in relation to the most relevant issues raised by the school system: whether the course only concerned the didactics of an individual discipline (most often physics) or rather was focused on different questions such as the problem of evaluation, digital education, school drop-out, etc.; *physics-specific* areas which refer to the different disciplinary topics that can be touched within the course, such as classical or modern physics, solid state, astrophysics, etc; and the *transversal* areas which characterize the course with respect to the inclusion of topics which are inter-disciplinary in education research, such as teaching methodologies, laboratory teaching, learning processes.

2.3. Objectives

This part of the questionnaire identified 19 educational objectives of the course, which were meant to cover practically all aspects of disciplinary knowledge, Pedagogical-Content Knowledge (PCK) [3] and Technological-Pedagogical Content Knowledge [4]. The objectives were arranged in groups which include the development of competencies related to 1) the design and realization of laboratories, 2) historical/epistemological aspects of the discipline, 3) the use of multimedia in education, 4) the design of coherent didactic sequences, 5) exercise management and problem solving, 6) the integration with interdisciplinary and social aspects; and the accumulation of disciplinary knowledge, in particular concerning 7) more in depth study of disciplinary topics included within the curriculum and 8) disciplinary topics not included in the high school curriculum.

2.4. Methods of delivery and means of evaluating course impact

The final part of the questionnaire concerned specific didactic methodologies which were used within the course delivery; in particular we investigated the method of delivery (whether using frontal lessons, laboratories, e-learning strategies, group discussion, and if different strategies where used, in which proportion) and the means by which data on the course impact were collected (i.e. typology of tests, questionnaires or any other type of task or product the teachers were required to complete or produce).

3. Results

The questionnaire was administered to all 36 locations of the national PLS-Physics. 33 locations responded to the questionnaire, for a total of 139 different courses reported. From the data emerges a wide and interesting variety of activities, which differ in organizational aspects, methods of intervention, objectives and didactic typology and outgoing skills.

3.1. Organizational aspects

3.1.1. Organization and location. In about 64% of cases the courses were organized on the initiative of the Universities, either individually or as a consortium (Figure 1) and in 68% of cases were held at University structures (Figure 2). A school-University collaboration took the initiative of starting the course in about 30% of the cases There is a significant overlap between the two pieces of information in the sense that about 85% of courses organized by an individual University, and 70% of those organized by a consortium, were held in University structures. On the other hand, about 50% of courses organized through school-University collaboration, these were held at least partially in schools. Concerning costs for teachers, 71% of courses were completely free, while in most other cases the fee could be covered by the yearly bonus teachers have available for in-service training, professional update or for buying professional equipment.

3.1.2 Characteristics of formators. The training courses were held mainly by permanent University staff (3.5 units per course on average, see Figure 3 for more details), sometimes with the support of PhD students or Postdoc researchers often acting as tutors (1.2 units per course on average) and teacher-formators (1.5 units per course on average). Indeed, more than half the PLS courses employed at least one teacher formator. Most of the courses (76%) took place in February / March, coinciding with the break from University lessons, while 20% of courses took place in the summer months, thus avoiding interference with teaching activities held both at University and school.

3.*1.3 Characteristics of attending teachers.* The recipients of the training actions were in a majority of cases (65%) high school teachers from all types of schools, while in 21% of the sample the course was reserved for teachers of the “Liceo Scientifico” (science-oriented high school). Globally, over four thousand teachers attended the reported initiatives (excluding course repetitions) with a percentage of student-teachers reaching the end of the course and obtaining a certification of over 91%. The number of participants in each course (Figure 4) varied, with a prevalence (about 65%) of courses less than 30 participants.

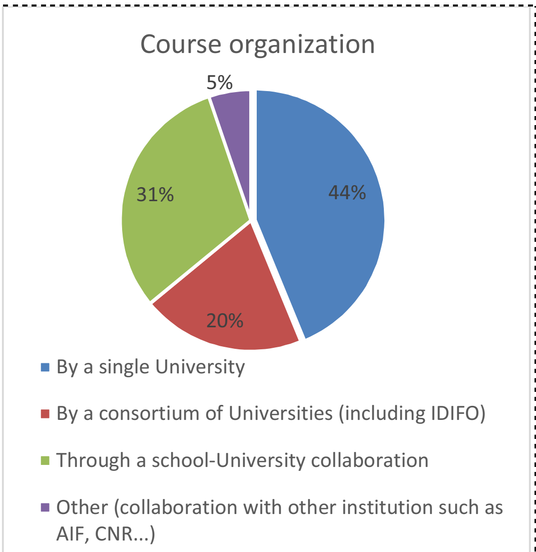

Figure 1. Initiative for the organization of the course.

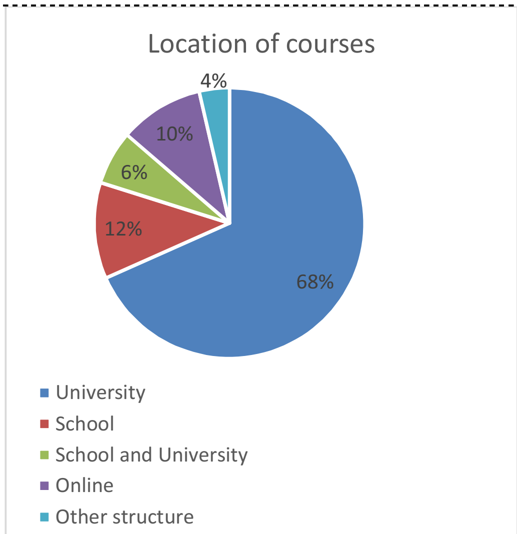

Figure 2. Location of courses.

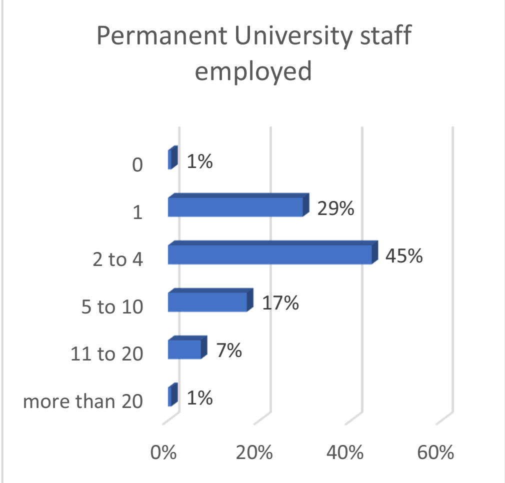

Figure 3. Number of permanent University staff employed as formators.

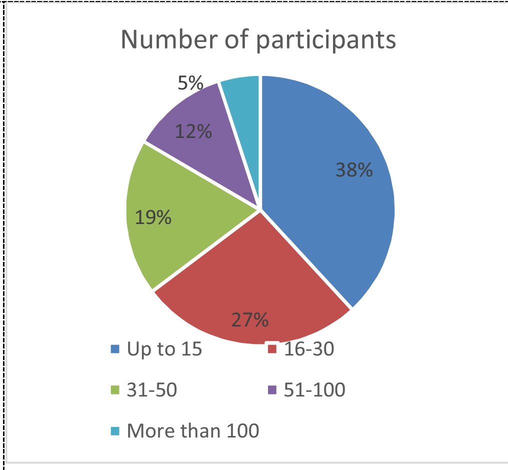

Figure 4. Number of participating student-teachers.

The number of participants per course is moderate, often due to the will of the organizers of providing teachers with more choice options and enact initiatives in which the teacher-student is an active protagonist of his training.

3.*1.4 General characteristics of courses.* About one third of courses did not require teachers to attend a minimum of hours, while for other courses a minimum attendance for course certification was required, which in 44% of courses was more than 60% of the total hours of attendance. The mean duration of courses (hours spent with the teachers of the course, either in presence or at a distance) was about 19 hours, organized on a mean of 6 encounters. Obviously, the total effort required to teachers was higher, since such time also includes individual study, design, re-elaboration; overall, the estimate of the total hour commitment is about 30% higher than the time spent working with teachers (26-27 hours on average per course). Details on the total effort required by courses in terms of hours are reported in Figure 5, where we can see that the courses are almost evenly divided between "shorter" (20 hours of total effort or less) and "longer" (more than 20 hours of total effort) ones. In Figure 6 we report the ratio between certified hours and hours of total effort, from which we read that courses in which less than 50% of teacher effort was certified were a small minority (9%). Finally, we note that 37% of the courses which were reported by participating Universities were held for more than one edition during the five years, bringing the total number of initiatives reported (including repeated editions of the same course) to 243.

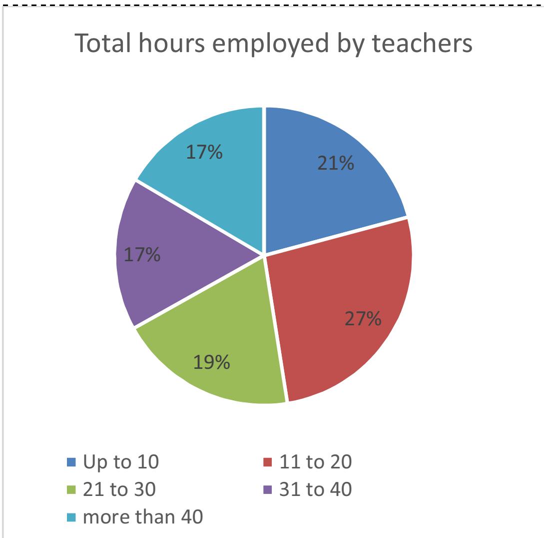

Figure 5. Hours of total effort required to teachers in PLS courses.

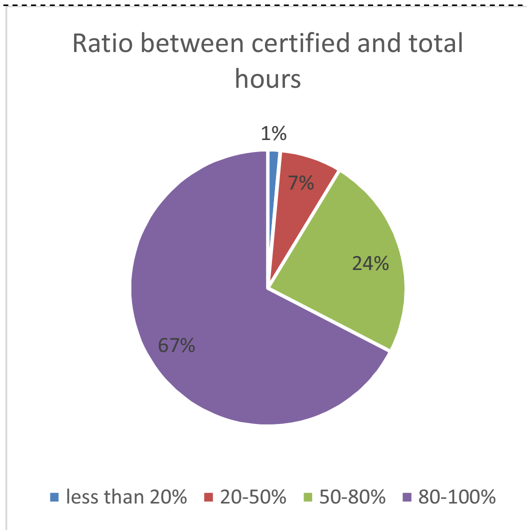

Figure 6. Ratio between certified hours and hours of total effort. In the cases in which hours were certified using University credits (CFU) they were translated into hours through the Italian standard (25 hours/CFU).

3.2. Areas of intervention

Concerning what we have called the specific institutional areas, as can be seen in Figure 7 the lion's share was taken, as expected, by the didactics of individual disciplines with 98% of courses including themes of disciplinary didactics; however, a significant fraction of courses addressed problems related to student guidance and counselling, digital education, individual assessment and environmental issues. Moving on to the specific areas of Physics (Figure 8), we note that overall, there are three very frequent topics, which were addressed each in about half of the courses: classical physics, quantum physics, and laboratory as physics content, including all its nuances (historical laboratories, exploration laboratories, ICT laboratories, etc.). Most of the courses (73%) had at least some modern physics content (including quantum physics, relativity, nuclear physics etc) which testifies the significant offer (which was connected to a significant demand coming from teachers after the 2012 curriculum reform) of professional development opportunities involving in modern physics topics.

Finally, the areas of intervention that have been designated as inter-disciplinary cover aspects of teaching are transversal across the disciplines. As shown in Figure 9, the two most frequently cited areas of intervention were transversal teaching methodologies (80%) and laboratory teaching methodologies (78%); while other areas receiving significant attention were those related to the study of learning processes (24%) to competence-based teaching (35%) and digital competencies for teaching (12%).

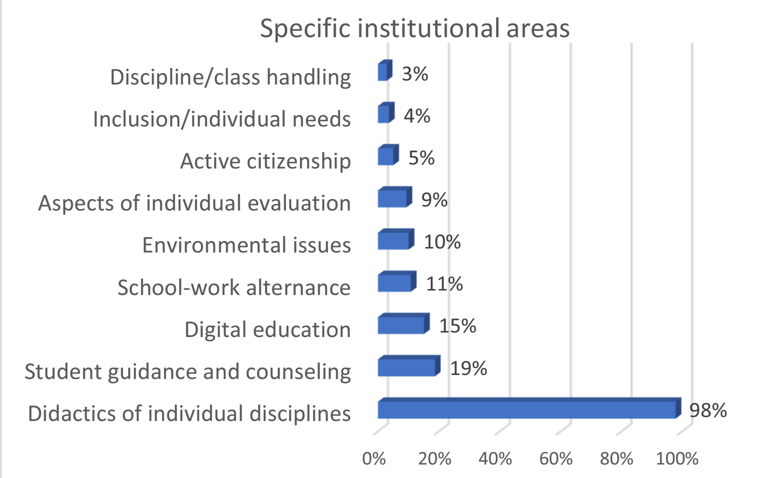

Figure 7. Division of courses according to interventions in specific institutional areas. For each course one or more areas could be reported in the questionnaire.

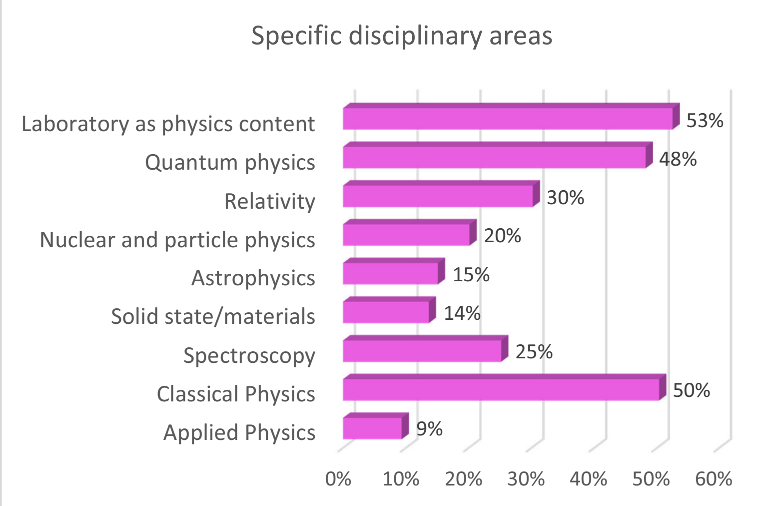

Figure 8. Division of courses according to interventions in specific areas of physics. For each course one or more areas could be reported in the questionnaire.

3.3. Objectives

As mentioned in the Introduction, the section of the questionnaire devoted to objectives presented a list of 19 items which were meant to cover essentially all the aspects of teachers' PCK and PCKT. For the purpose of a concise presentation in this article the objectives were reduced to eight macro-objectives, in some cases by grouping several items into common themes. In this way, we identified as the more relevant goals those related to the deepening of knowledge of curriculum topics (75% of courses); acquisition of new knowledge with respect to the secondary school curriculum (52% of courses); and objectives related to the design and realization of laboratory activities (60%). A relevant share (41%) of courses had objectives related to the coherent design of educational sequences, with integration of different aspects (digital technologies, interdisciplinary aspects, experiments) while other important goals were related to the management of exercises and problem solving (20%), the historical and epistemological framework of the discipline, which includes Nature Of Science (NOS) aspects (24%), the integration with other (science or non-science) disciplines and with social aspects (29%), and the integration of multimedia in disciplinary teaching (19%). An overview of these macro-objectives is shown in Figure 9. From a finer view on specific objectives, we can point out that a very large percentage of courses (61%) have the specific goal of providing teachers with more in-depth knowledge of modern physics, consistently with the data reported in the physics-specific areas of intervention.

3.4. Methods of delivery and means of evaluating course impact.

3.4.1. Methods of delivery. The training activities were divided in sessions which used a variety of educational strategies; besides frontal lessons (used in 86% of courses), the initiatives adopted laboratory work (69%), plenary discussions (76%), other types of non-laboratory group work (53%). In addition, the courses adopted not in presence autonomous design (45%) and in some cases e-learning strategies (24%). In Figures 11-16 we show the relative weight of these techniques for the courses reported, i.e. the fraction of the total hours effort delivered through each strategy. Overall, we may note the following relevant data: the mean usage of frontal didactics in the courses reported was not very high (about 32% of course time on average), almost on par with the mean course time devoted to small group activities (18% in the laboratory, and 9% other). Online teacher education has not been very widely used: 105 out of 139 courses (76%) had no e-learning content, and a vast majority of the courses which had significant e-learning content were comprised within the IDIFO-6 (2017-2019) online Master on modern physics for teachers [5].

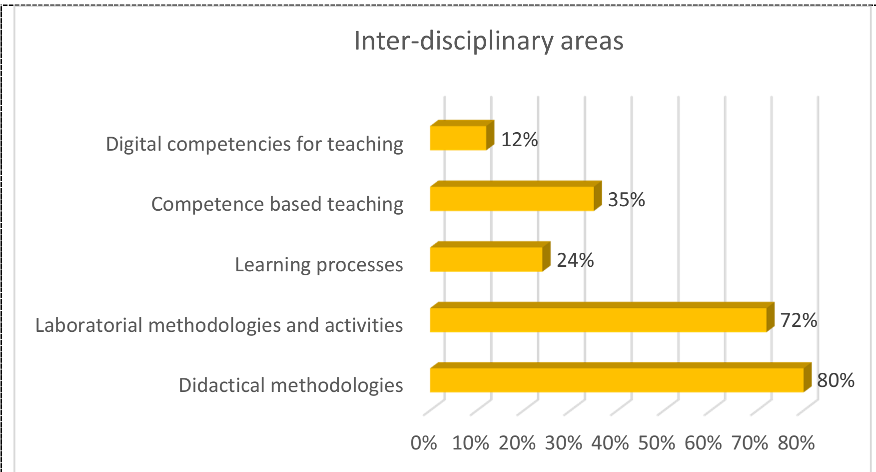

Figure 9. Division of courses according to interventions in interdisciplinary areas. For each course one or more areas could be reported in the questionnaire.

3.4.2 Means of evaluating course impact and acquired skills. In most cases (84%) the courses proposed no entrance test. This is not necessarily to be seen as a negative characteristic, presumably evaluating the course effectiveness through a traditional pre-post monitoring was not a priority of the organizers, who privileged employing time in the designed educational activities. On the other hand, those 4% of courses (see Figure 16) which proposed a very extensive (more than 3 hours) entrance test were probably going through a very detailed effectiveness study, or a Design Based Research (DBR) cycle [6]. On the other hand, 82% of courses reported some means of collecting post-course feedback. In 28% of cases this was in the form of an approval/satisfaction questionnaire; note that for courses which were institutionally registered through the SOFIA platform of the Italian Ministry of Education [7] a satisfaction questionnaire is automatically offered to attending teachers. In many other cases the feedback consisted in the presentation of teacher's products, be they examples of educational design (32%), written reports (14%), rarely conceptual maps (1%) or other products (24%). A formal post-test was used in 13% of cases, while other, less used forms of feedback were a final discussion (4%) and a test of laboratory skills (1%).

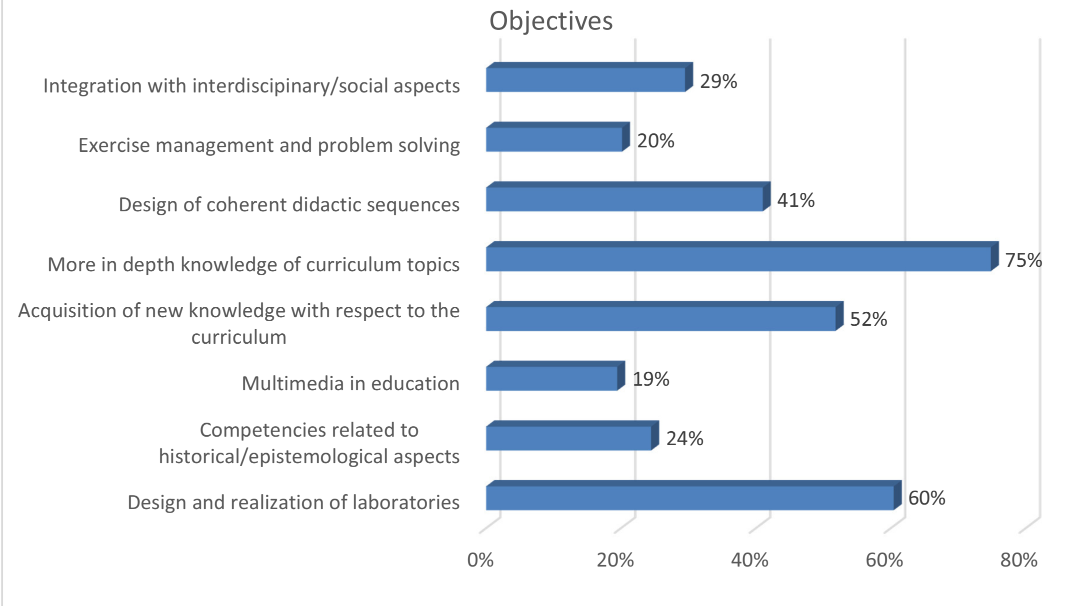

Figure 10. Objectives of courses, grouped into categories. For each course, up to 5 options (in the original list of 19 specific objectives, see the article text) could be selected.

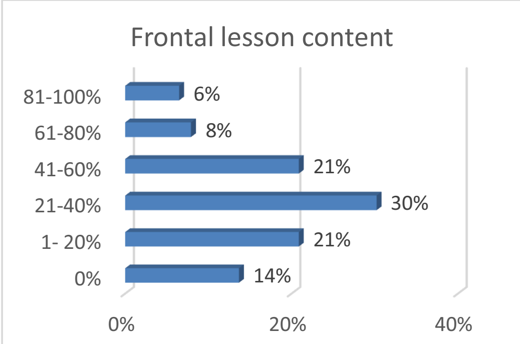

Figure 11. Frontal lesson content of courses, expressed as percentage of the total required hours.

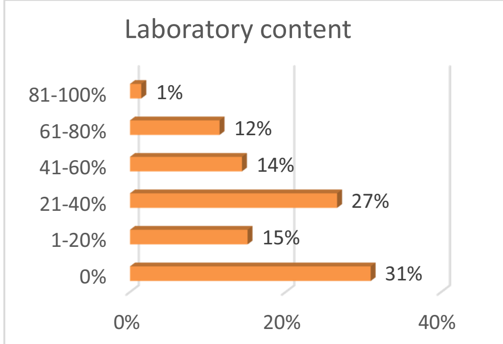

Figure 12. Laboratory content of courses, expressed as percentage of the total required hours. Here, both group laboratory and demonstration laboratory are included

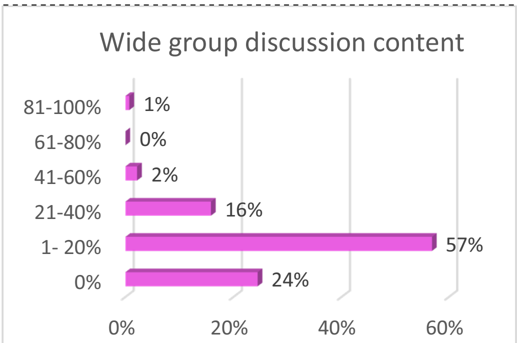

Figure 13. Wide group discussion content of courses, expressed as percentage of the total required hours.

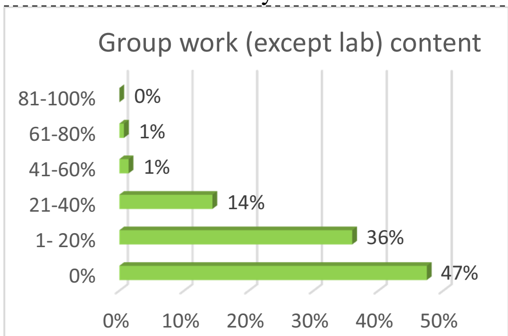

Figure 14. Group work (not in the physics laboratory) content of courses, expressed as percentage of the total required hours.

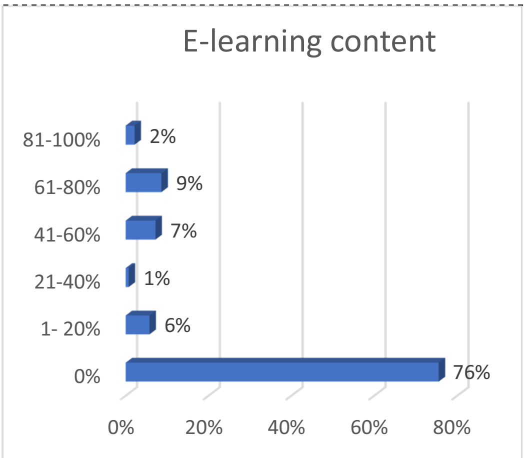

Figure 15. E-learning content of courses, expressed as percentage of the total required hours.

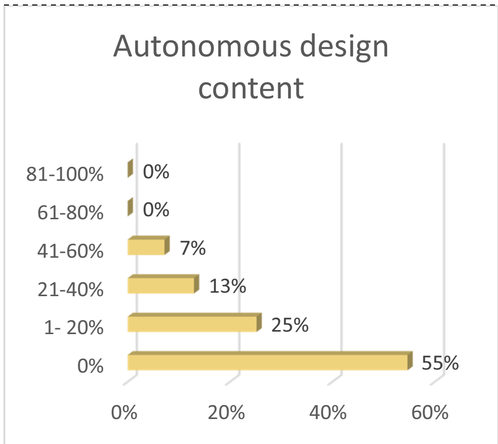

Figure 16. Autonomous design content of courses, expressed as percentage of the total required hours.

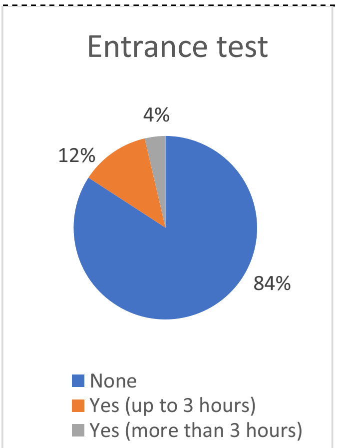

Figure 17. Fractions of courses including an entrance test.

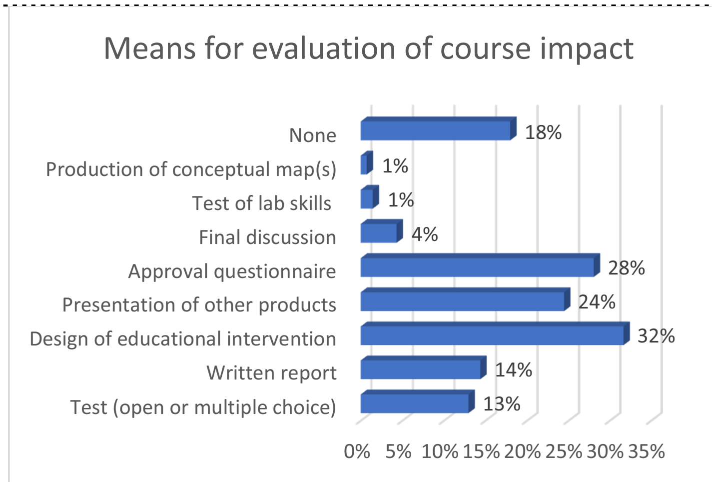

Figure 18. Means for evaluation of course impact adopted in the reported courses-

4. Discussion and conclusions

The questionnaire we developed explored the teacher professional development activities enacted within the project PLS-physics, an institutionalized network of University educators engaged in the improvement and development of various crucial aspects of the Italian educational system, including in service teacher formation. Even though the data presented here is limited to teacher training actions which were implemented in the last five years, they manage to capture the richness and diversity of experiences and initiatives undertaken by PLS-Physics on the Italian panorama.

According to our data, the teacher education initiatives offered had a significant impact on in-service teacher professional development in Italy and contributed to consolidate the relationship between school and University, also through the training of teacher-formators. Furthermore, we can now make some conclusive remarks on the data emerging from our study. Concerning the disciplinary areas of intervention, the data analysis highlights a significant accent on initiatives in two fields: modern physics (often more specifically quantum physics) and the physics laboratory. In part, such emphasis may be a feature of the Italian system of teacher recruitment, in which graduates with a degree in mathematics can often be enrolled as teachers of both mathematics and physics with little or no further instruction. In this case, comprehensibly, modern physics and the laboratory are the areas in which they will feel weaker, expressing a demand for development opportunities. Another factor to consider is the relatively recent curriculum reform (2012) which considerably expanded the presence of quantum physics topics in the final year programs; after such reform, all PLS partner Universities experienced a very strong direct demand coming from their respective teacher networks of formation on quantum physics.

Our data confirm the centrality of the laboratory in physics teacher education, a context for consolidating conceptual representation of phenomena, developing mathematical formalization, and adopting methodological innovation. This leads us to a second comment on the results of our data, concerning the significant penetration of PER-based techniques in the professional development opportunities offered by PLS. This emerges for example from the high percentages of courses treating methodological aspects of teaching (Figure 9), the moderate use of frontal lessons in the delivery of courses with respect to other, more cooperative strategies (Figures 11-16), the emphasis on the design of laboratory activities and of didactical sequences integrating different aspects such as experiments, digital technologies, interdisciplinary aspects (Figure 10). These data are extremely encouraging as one of the main objectives of the in-service teacher training action was precisely to stimulate significant and effective changes in the teaching practice of the teachers involved.

On the side of partly critical remarks, the data show that the capability of collecting feedback on course impact based on PER research methods has room for improvement and could benefit from a higher level of coordination between the PLS partner Universities, since the actions undertaken to evaluate the changes in teachers' practices produced by the professional development initiatives were diverse and generally not systematic (Figures 17-18). An important direction to take as a community would be to collect data on the effects of teachers' professional learning on students, not only in terms of learning outcomes, but also of interest and motivation. Systematic feedback of teachers on these issues taken right after the courses would provide a very relevant input. We can also note that online teacher education has not been very widely used within PLS in the past (Figure 15). Most courses had no e-learning content, and a vast majority of the courses which had significant e-learning content were comprised within the IDIFO-6 (2017-2019) online Master on modern physics for teachers, organized by the University of Udine in collaboration with other PLS member Universities. In this case the situation is currently undergoing extremely rapid change due to the COVID-19 pandemic, which is forcing a much more extensive use of e-learning techniques. The experience accumulated during the present period will presumably be useful in the future for the purpose of offering to more and more teachers throughout the National territory, the opportunity to participate in professional development initiatives.

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