PROCEEDINGS OF SCIENCE

Improving teaching through research experience

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We describe the experience of a residential professional development program for high school teachers, known as PID (Programma INFN per Docenti). Each course is structured as a week-long activity, from Monday to Friday, and combines lectures with four hands-on laboratory sessions through which participants, organized into small groups, rotate. Both the lectures and the laboratory activities are directly linked to the research carried out at the INFN host facility.

The central idea of the program is to encourage teachers to reinterpret and adapt the acquired knowledge into educational activities, drawing on their own creativity and professional expertise. The program aims to provide participants with a comprehensive understanding of INFN research in Italy, to strengthen or develop laboratory measurement skills, and to foster direct and sustained interaction with researchers. In addition, the residential format supports the creation of professional networks among participants, promoting the exchange of knowledge, experiences, and opportunities such as courses and internships. We conclude by reporting and discussing the results obtained within the framework of the program.

The European Physical Society Conference on High Energy Physics (EPS-HEP2025)
7-11 July 2025
Marseille, France

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1. Introduction

The National Institute for Nuclear Physics (INFN) is a public research organization under the supervision of the Italian Ministry of University and Research. Its mission is to conduct research in (sub)nuclear and astroparticle physics, develop related instrumentation, and disseminate results to the scientific community and society. INFN operates four national laboratories in Catania, Frascati, Gran Sasso, and Legnaro, along with national centers and university-based sections, and jointly manages the European Gravitational Observatory (EGO) with CNRS and NIKHEF. While INFN is internationally active at major facilities such as CERN and Fermilab, its research activities and national presence remain less widely known to the public. In addition to fundamental research, INFN carries out interdisciplinary and applied activities with direct societal impact.

Since the early 2000s, INFN has offered professional development courses for high school teachers. This paper focuses on the INFN Teachers Program (PID), a week-long residential course launched in 2018–2019, in which teachers attend lectures and perform experimental activities at INFN laboratories. After a pause in 2020 due to COVID-19, the program resumed in 2022; the results discussed here mainly refer to the 2022–2024 period.

2. Methodology

The literature [1] shows that immersing science teachers in active research environments improves professional practice by providing hands-on research experience, updating knowledge of frontier science and technologies, increasing awareness of opportunities for students, and fostering professional communities and informal networks.

In the PID program, participants work in small groups, spending about half of their time on physics measurements and the remainder on lectures and facility visits. The experimental activities, derived from the host laboratory's research, are carried out in close collaboration with INFN staff and are not designed to be directly transferable to classroom practice. Instead, participants are encouraged to translate the acquired knowledge into educational activities using their own pedagogical skills. This approach promotes the teaching of physics through an experimental approach, collaborative teamwork, and direct interaction with researchers.

This model differs from traditional professional development courses and shares similarities with U.S.-based research programs such as STAR and the Columbia University Summer Research Program (CUSRP) [2]. While these initiatives have demonstrated positive impacts, their extended duration and high costs limit participation. In contrast, PID's shorter format and lower costs allow broader participation. To our knowledge, no comparable programs currently exist in Italy, although the model appears well suited for replication.

2.1 Structure of the program

The initiative was designed with the objectives of delivering a high-quality professional development experience, providing an updated overview of INFN research and its societal applications, supporting teachers in integrating research topics into their teaching, strengthening links between INFN and secondary schools, and fostering professional networks among teachers and host laboratories.

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TIME	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
9:00	Director's Welcome Safety Course	Cultural Heritage without Accelerators	Radiofrequency Cavities and Cyclotrons	Radiobiology	Radiopharmaceuticals
11:00	Electrostatic and Linear Accelerators	Guided Tour of LNL	Cultural Heritage with Accelerators	Women and Science	Round Table Conclusions
13:00	Lunch	Lunch	Lunch	Lunch	Lunch
14:00	Laboratory	Laboratory	Laboratory	Laboratory	Free

Figure 1: Agenda of the 2018 PID course at LNL, Laboratori Nazionali di Legnaro

PID is hosted at selected INFN research facilities, each focusing on specific research areas, including neutrino and dark matter physics (Gran Sasso National Laboratory), nuclear and neutrino physics and hadron therapy (Southern National Laboratory), nuclear physics and its applications in medicine and cultural and environmental heritage (Legnaro National Laboratory), and gravitational-wave detection at the European Gravitational Observatory (VIRGO). The Frascati National Laboratory, the leading centre for the development of future techniques of particle acceleration, will join the program in 2026.

Participants may attend one course per year and cannot repeat the same laboratory. With cohorts limited to 25–30 participants to ensure effective laboratory work, teachers are embedded in the research environment of the host institution, gaining direct exposure to advanced research, experimental methods, and INFN facilities, while developing professional relationships with researchers. They actively perform experiments linked to ongoing research and are responsible for transferring the acquired knowledge into classroom practice.

The program lasts five working days, aligning with nationally recognized professional development provisions. Lectures are scheduled in the mornings and laboratory sessions in the afternoons, with participants working in small rotating groups to ensure full hands-on engagement and peer interaction. Informal professional networks naturally emerge from this structure and represent an important element in empowering science teachers [3].

In addition to research-focused lectures and laboratory activities, the program includes topical seminars on INFN opportunities for high school students and on the gender gap in STEM. The latter, delivered by external experts and followed by moderated discussions, aims to raise awareness and highlight the role of teachers in promoting inclusivity, with feedback collected at the end of each course. A typical agenda is shown in figure1.

2.2 Selection of participants

Participants are selected through an annual open call advertised via mailing lists and social media. Each course hosts 20–30 teachers, with a maximum of three courses per year, for fewer than ninety available positions. Applications consistently exceed capacity by a factor of three to six.

Applicants submit information on their school, teaching activities, and motivation, which are evaluated by a scientific committee. To ensure geographical diversity, participants are selected

	2022-2023	2023-2024	2024-2025
LNL	4.9/4.7	4.9/4.7	4.9/4.6
LNGS	4.8/4.4	4.9/4.7	N/A
LNS	N/A	4.8/4.3	4.9/5.0
EGO	N/A	N/A	4.6/4.0

Table 1: Satisfaction survey. First score is the average score of lectures; second score is the average score for laboratory activities

from all represented regions, and teachers may reapply only for different host laboratories. Since its launch in 2018–2019, the program has involved approximately 370 teachers, with about 270 attending at least one course.

Participants cover a modest registration fee and their travel and meal expenses, while INFN provides accommodation and covers all costs related to laboratory activities and seminars. Additional visits to nearby research facilities are supported through external sponsorship.

3. Results

From the outset, the program was conceived with a multi-level evaluation framework to assess its impact at different stages.

The first level consists of a satisfaction survey administered at the end of the week, providing immediate feedback.

The second level addresses learning outcomes: each participant group produces a short scientific paper describing one of the experiments performed, published as an internal report of the host research centre and contributing to collaborative learning.

The third level evaluates the impact on teaching practices through an ex post survey conducted about one year after participation, collecting information on classroom changes, developed activities, and knowledge sharing with colleagues.

The fourth level focuses on the impact on students, in terms of skill development and involvement in formal or informal activities stimulated by the course.

These data are obtained through the same ex post survey and complemented by institutional records of laboratory visits, internship applications, and participation in INFN initiatives for high school students. The end-of-week survey also collects detailed feedback on lectures and laboratory activities. Lectures are evaluated based on scientific competence, communication skills, time management, and the adequacy of prior knowledge, while laboratory activities are assessed in terms of interest, preparatory adequacy, relevance of prior knowledge, transferability to classroom practice, and satisfaction with the depth of analysis. The results, summarized in Table 1, show consistently high approval ratings on a five-point scale for both lectures and experimental activities.

3.1 Impact in the classroom

The primary goal of the ex post survey is to assess the impact of the PID program on classroom practice. Although the survey was planned from 2019 onward, the interruption caused by the COVID-19 emergency delayed its implementation. Consequently, data were collected for the

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Question	2022-2023 (turnout: 91%, N=55)	2023-2024 (turnout: 96%, N=79)
Did you share material with colleagues	Yes 65%	Yes 68%
Did your teaching change?	Yes 55%	Yes 68%
How many times did you use material from the course?	Often 14% Sometimes 61% Rarely 18% Ever/No Answ. 7%	Often 14% Sometimes 68% Rarely 14% Ever/No Answ. 4%
Did your didactic planning change?	Yes 40%	Yes 72%

Table 2: Sample of questions of the ex-post evaluation survey

2022–2023 and 2023–2024 academic years. The results indicate a positive and encouraging impact on teaching practices. A representative sample of responses is reported in table .

Among teachers who reported using materials from the course either "often" or "sometimes" (approximately 75–80% of respondents), nearly 90% stated that their teaching had improved. In addition, many participants reported increased ability to actively engage and motivate students by drawing directly on the experiences and activities carried out during the program.

Open-ended survey questions further provide qualitative evidence of an increased use of laboratory-based activities, particularly among participants who had limited prior experience with experimental teaching. Respondents also reported improvements in the design and implementation of interdisciplinary activities, a result that is consistent with the high proportion of teachers (approximately 65%) who shared materials and experiences with colleagues.

The survey also investigated the introduction of new opportunities for students following participation in the program. Approximately 60% of respondents reported having enrolled their classes in INFN outreach initiatives. Whenever possible, these self-reported data were cross-checked against internal records of laboratory visits, internships, and other activities, showing excellent agreement. As an illustrative example, Table X lists the activities promoted by the twenty-six teachers who participated in the LNL-2023 course: three guided laboratory tours (out of a maximum availability of two per month), eleven seminars with INFN researchers, seven cases in which teachers encouraged students to attend a one-week applied summer internship at an INFN laboratory, and twelve new instances of school participation in INFN initiatives for high school students.

With respect to the development of informal professional networks, evidence suggests that social media groups (e.g., WhatsApp) created during each course are actively used to exchange news, teaching experiences, and information on professional opportunities, not limited to INFN-related activities. Notably, many of these groups remain active for several years after the course. During the COVID-19 lockdown periods, these networks proved particularly valuable as channels for maintaining contact among teachers strongly committed to improving their teaching practices.

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Monitoring of these groups indicates, for example, that a WhatsApp group formed during a 2021 course generated approximately fifty non-INFN-related initiatives over a three-year period.

An unexpected positive outcome emerged with regard to the geographical distribution of participants. Ex post surveys revealed that a substantial proportion of attendees (around 60%) teach in towns with fewer than 100,000 inhabitants, and approximately 40% in towns with fewer than 50,000 inhabitants—areas that are often distant from major academic research centers. Although INFN units are distributed throughout the country, they are typically associated with university physics departments, making participation less accessible for students in more remote locations. Teachers from these areas can therefore act as crucial intermediaries, strengthening connections between INFN and students living in inner or peripheral regions that would otherwise be difficult to reach.

4. Conclusions

PID has proven to be a successful initiative. Results from the ex post surveys conducted approximately one year after participation indicate clear positive effects on teaching practices, including an enhanced capacity to design interdisciplinary projects and a deeper understanding of how laboratory activities can be effectively integrated into classroom instruction. The objective of strengthening the connection between INFN laboratories and the broader public is also being successfully addressed, as the program enables outreach to students attending schools located far from INFN facilities.

Although the program is demanding in terms of both human and financial resources, the observed improvements in teaching quality confirm the overall effectiveness and value of the initiative. Current efforts are focused on expanding the program to include additional INFN facilities, through appropriately tailored formats, and on organizing focus groups with former participants in order to assess the long-term impact of the program.

Acknowledgments

We gratefully acknowledge the contribution of all INFN staff at the host laboratories, including scientists as well as technical and administrative personnel. We also sincerely thank Sanoma Italia for its continued and long-standing support of the program.

PID is a project funded by the INFN Third Mission Coordination Committee (CC3M).

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