PROCEEDINGS OF SCIENCE

Bringing research, education and outreach into dialogue: the INFN-INSPYRE school case study

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In recent years, increasingly more universities and cutting-edge research institutes propose outreach activities addressed to school students. For some of these initiatives, participants become part of the research setting, interact with researchers, raise awareness of the numerous applications of research in everyday life, and conduct experimental activities firsthand, and a general effort of synergy between scientists and outreach and physics education communities is starting to become visible. An example of this approach is provided by the 2024 edition of INSPYRE, the International School of Modern Physics and Research. The School, organized by INFN at Frascati National Laboratory and addressed 39 high school students from 7 countries, drawn upon the collective experience and expertise of researchers from INFN and other institutes. Collaboration with key members of the educational and outreach communities at CERN and GIREP, also made the program richer and innovative, and fostered a constructive dialogue among the communities involved.

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1. Introduction

Dealing with modern physics is a valuable means of inspiring high school students to pursue STEM careers and providing them with the tools to make informed choices [1, 2]. This is even more true when the activity is held in cutting-edge laboratory with hands-on experiments; in this case, in fact, students can immerse themselves, become part of the research setting, interact with researchers, raise awareness of the numerous applications of research in everyday life, and conduct experimental activities firsthand [3-6].

In recent years, more and more of such initiatives are being carried out by universities and research institutions and show their impact [7]. In addition, a new general trend is increasingly gaining ground: making these proposals even more rich and effective through a synergy between scientists and the outreach and physics education communities, that allows to draw from diverse perspectives and disciplines [8].

The 2024 edition of INSPYRE, the International School on modern PhYsics and Research addressed to high school students [9, 10], fits into this trend. Held at the Frascati National Laboratory (LNF) of the Italian National Institute for Nuclear Physics (INFN), the School benefited not only from the collective experience and expertise of researchers of INFN and other institutes, but also from collaboration with key members of the educational and outreach communities at CERN and GIREP. In this paper, we will illustrate the steps of this collaboration and the impact it had on the School.

2. The INSPYRE School

INSPYRE is a one-week school focused on modern physics and addressed to a group of 40 students from all over the world attending the last two years of high school [9, 10]. It is organized by INFN and held at Frascati National Laboratory, the largest facility in Italy dedicated to the study of nuclear and subnuclear physics with accelerators and its applications. Its main aim is to use modern physics to bring participants closer to STEM careers, with a hands-on and experimental approach. During the week, students experience a full immersion in the Laboratory environment and attend plenary lectures, perform laboratory-based activities, discuss with researchers, socialize. In this way, they become protagonists of their own learning while getting to know INFN's and other institutions' research facilities and professionals.

From its first edition in 2011, INSPYRE reached and had an impact on more than 600 students from 18 different countries [9], thus representing a quite well-established outreach activity. For this reason, it represented an ideal space where it was possible to experiment new approaches, that could help us to broaden the range of topics covered, present them in an even more effective and engaging way and introduce tools that would allow us to assess students learning in a more systematic and research-based way. To do this, for the 2024 edition we decided to involve the educational and outreach communities of the European Organization for Nuclear Research (CERN) and the International Research Group on Physics Teaching (GIREP) and treasure their expertise even from the early organizational stages of the School.

2.1 INSPYRE Scientific Committee

The first step to bring communities into dialogue was to create a Scientific Committee, responsible for defining the scientific program of the School and identifying researchers to be

involved, that could give voice to the different expertise we want to include. The 2024 Committee was therefore formed by INFN researchers with diverse backgrounds, fields of study, and different sensitivities and experiences in outreach and educational activities; moreover, Sascha Schmeling, the Head of Teacher and Student Programmes at CERN, and Marisa Michelini, leading member and former president of GIREP graciously agreed to participate in the project. The complete list of members to the INSPYRE Scientific Committee can be found at [11].

The Scientific Committee identified a series of aspects to be cared about in planning the School. First, the School should have treated both physics topics grounded in INFN research, such as quantum physics, high energy physics, accelerators, particle detectors, and other scientific topics that would have interested and intrigued students. Indeed, INSPYRE has always paid attention to this aspect, hosting contributions on topics such as astrophysics, applied physics and medical physics. For the 2024 edition, contributions on nuclear physics application, astrophysics, medical physics, cultural heritage conservation, environmental monitoring, as well as a focus on Artificial Intelligence, chosen for its topicality, were welcomed.

Secondly, the INSPYRE scientific program should have approached the same topic from multiple perspectives, giving participants the opportunity to interact and share ideas and questions. For this reason, we decided to accompany the lectures with debates, moments in which students could approach the same topic from a different, more applied point of view, and share their doubts and questions after a brief introduction from the speaker. For example, the Artificial Intelligence lecture, held by Alberto Pace, researcher at CERN, was followed by an interesting debate on the application and significance of this technology also to education, guided together with Sascha Schmeling. Moreover, we paid attention to select experimental activities in line with the lecture topics; to these activities, three whole mornings were devoted; the complete list of experiments can be found at [12].

We also decided to offer during the School a well-structured path rooted in Research in Physics Education. Together with Marisa Michelini and her group, we decided to focus on Quantum Mechanics foundations, a topic that her research team has worked on extensively over the years [13], and combining it with an INFN line of research, Quantum Computing, which represents one of its cutting-edge applications. For this educational path, we assessed students' learning making use of in- and out- tests and tutorials that served as a guide for students during the activity.

2.2 The 2024 edition of INSPYRE

The 2024 edition of INSPYRE came to life under the title "*From Quantum Foundations to Artificial Intelligence*" to reflect our dual goal of covering fundamental physics subjects while also paying attention to hottest topics in science. The final scientific program was structured as following:

- **7 lectures** (Accelerators, Particle detectors, Standard Model, Gravity, Artificial Intelligence, Quantum mechanics foundations, Quantum Computing)
- **5 debates** (Quantum Mechanics and Quantum Computing, Nuclear physics application, Messengers from space (Gravitational Waves and neutrinos), Artificial Intelligence, What is yet to be discovered in physics)

- **11 experiments**[1] (Particle detectors, Simulation techniques for medical applications, Environmental monitoring, Superconductivity, Diagnostics and preservation of Cultural Heritage, Plasma sources for particle accelerator, Cosmic rays, Gamma spectrometry, Atoms, X-rays and Synchrotron Radiation, Exploring polarization by means of polaroid and birefringent crystals)
- **Special events** (Art&Science Event, Young People of LNF)

Two of the seminars (Quantum mechanics foundations, Quantum Computing), together with one experiment (Exploring polarization by means of polaroid and birefringent crystals) and one debate (Quantum Mechanics and Quantum Computing) gave life to the educational path [14].

4. The impact of the School

The 2024 edition of INSPYRE was held from 8 to 12 April 2024 at INFN Frascati National Laboratory and welcomed 39 high school students from 7 countries (Italy, French, Germany, Romania, Spain, Serbia, Slovakia); overall, 35 researchers and 5 staff members of the Education and Public Outreach Service of LNF were involved in the realization of the School.

To measure the impact of the School, we administrated to our participants two questionnaires: one before and one after the School. If the pre- questionnaire served as a mean of knowing more about the participants, their previous interest toward science and STEM careers and their expectations about INSPYRE, the post- questionnaire was intended to measure students' evaluation of the School activity and assess any changes of their perceptions. Out of 39 participants to the School, we obtained 35 responses to the first questionnaire and 36 responses to the second.

Due to space constraints, we report here only the set of questions of the post- questionnaire that tackle the main objective of the School: the link between INSPYRE and students' ideas about physics research and their possible future careers in STEM field. In **Figure 1** the percentages for the responses are reported and compared with analogous answers of the 2023 edition.

For all questions showed, a marked improvement in the answers can be noticed. All students claimed that INSPYRE was useful to give them an idea of what is done in scientific research (with more than 90% of them voting *very much*); more than of them 90% declare that they are more aware of the usefulness of physics in society (70% *much* more); 80% of students consider the goal of working in the scientific field more achievable for them after attending INSPYRE (46% claimed *much* more achievable); finally, more than 90% of them is more inclined to pursue a career in the STEM area (with more than 70% much more inclined).

This positive trend is also confirmed by the comments left by students at the end of the School. When asked what they are going to take with them from INSPYRE, the overwhelming majority of them cited extremely positive elements regarding their personal sphere ("*the people I met, the things I learned and the curiosity that has grown all along the week*", "*Good memories, new knowledge and new friends*") but also their view of science and scientists ("*My understanding of who physicists are*", "*The hope in physics research*", "*The inspiration of science*") and their

[1] Among these 11 experiments, students could choose two, to be performed in groups during two whole mornings. The experiment dedicated to the exploration of polarization by means of polaroid and birefringent crystals was common to all students and was carried out on a third morning.

renewed motivation to pursue scientific studies or careers as scientists ("*a strong motivation to become a physicist*", "*A lot of material to study, a lot of encouragement to go further in the topics I enjoyed the most and a lot of ambitions*", "*That I should not ever give up and always pursue my goals and dreams even I am not the best one*").

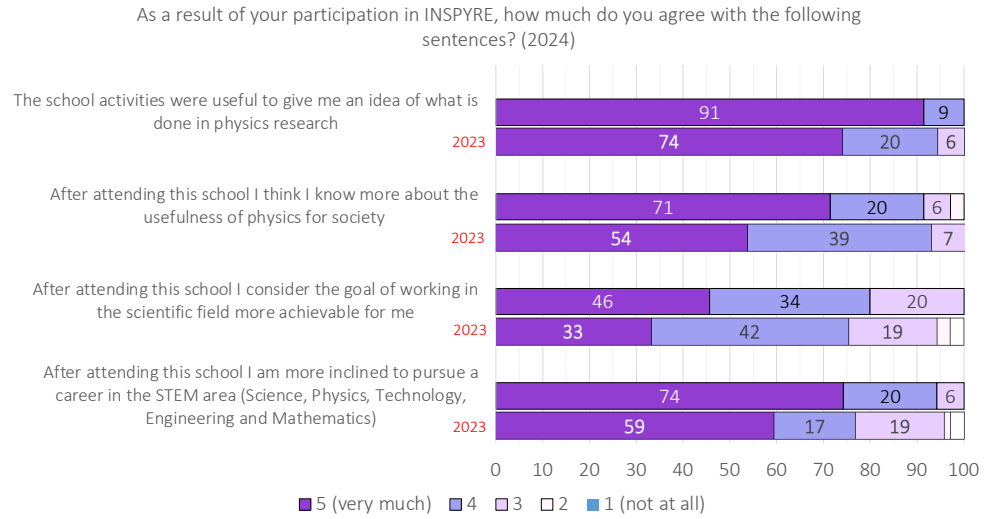

Figure 1 – The percentages for the responses obtained to some of the questions administrated to the participants of the 2024 edition of INSPYRE after the School, compared with analogous questions of the 2023 edition.

5. Discussion and conclusion

The 2024 edition of INSPYRE organized by INFN at the LNF for 39 high secondary school students from 7 countries saw for the first time a structural collaboration of the INFN scientific community with the outreach and education communities of CERN and GIREP.

Starting from the definition of the scientific program to the selection of speakers and activities, a great care was taken in representing the different communities involved, creating an innovative and rich proposal that could draw on different expertise. This led to numerous results.

First of all, the School program was enriched with new topics and approaches. Student participation was encouraged through debates and experiments, which were well incorporated into the lecture plan. Moreover, for the first time, an educational path on quantum mechanics was proposed, which, starting from an already optimized activity rooted in the Physics Education Research, exploited INFN expertise and knowledge. For this proposal, we started to investigate the learning objectives achieved by students through research techniques. The results of this didactic approach will be presented at two educational physics conferences, the World Conference on Physics Education 2024 [14] and the Congress of the Italian Physical Society [15].

Therefore, the 2024 edition of INSPYRE not only proved to be even more effective in bringing students closer to STEM careers, making them more aware of the work of researchers, the usefulness of physics in society and their possible future involvement in STEM careers. Indeed, it has become a place for discussion and exchange between different communities and the basis for joint work, which can be expanded even more in the future.

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