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Particle Physics at Primary Schools: a Report on the Italian Project

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Abstract: We report on an ongoing project aimed to teach particle physics in primary schools. The project is based on the original format by C.Lazzeroni and M.Pavlidou at the University of Birmingham, UK. The Italian version of the project emphasizes the following aspects: 1) the relevance of the teachers' training in order to make the project sustainable on a large scale and for a long period of time, overcoming the risk of occasional interest arousal about Particle Physics; 2) importance of an integrated approach where the Particle Physics workshops are put into the context of the regular learning school activities as well as outreach activities for parents. The program has run in six primary schools in Northern Italy since 2017 and it has evolved into a structured training program for teachers in collaboration with INFN in 2019. From the experience gathered in these years, the main benefits of the project include increased motivation, improved attitude towards science, and reduced gender bias in science-related activities.

Keywords: particle physics; teaching modern science; contemporary learning sciences

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1. Introduction

Science and technology play a prominent role in our society. The Council recommendation on key competencies for life-long learning of 22 May 2018 [1] makes reference to the need of "motivating more young people to engage in science related careers" [1] (recital n.12). A particular useful strategy in pursuing this goal is "link science education more closely with the arts and other subjects, using inquiry-based pedagogy, and engaging with a wide range of societal actors and industries" [1] (recital n.16).

In recent years substantial evidence has been gathered about the pivotal role of science teaching in primary schools in order to foster key competencies in science-related subjects and in order to improve the perception of attractiveness of science and science-related jobs [2].

Along these lines an innovative program has started in 2015 at the University of Birmingham by C.Lazzeroni and M.Pavlidou [3-5], aiming at introducing in primary schools Particle Physics concepts, that open up fundamental issues as the basic constituents of matter and the origin of our Universe, through the direct engagement in schools of researchers active in the field (as part of their outreach duties) as well as fostering the ongoing teacher eduction in these subjects.

Since 2017 the program has been implemented in six primary schools in Northern Italy at Istituto Comprensivo "Enrico Fermi" in Carvico. The Italian version of the project has two main goals:

I) To support the education of teachers on particle physics through a direct connection with researchers active in the field;
II) To support the idea that "teaching by teachers mentored by scientists" can be, on the medium-long term, highly effective. The joint collaboration between scientists and

teachers can benefit both in several ways: the impact of the teaching activities can be greatly enhanced by taking into account the especially positive attitude towards learning of young pupils that is well-known to teachers (and maybe less to researchers in particle physics or other science and technology fields); correctness and rigour of the material presented is guaranteed through the constant supervision promoted by professional researchers participating into the project.

2. The metodology

The Particle Physics program for primary schools relies on learning material and on a well-established set of teaching activities designed to improve teaching and arouse the interest of the pupils, developed at the University of Birmingham.

The learning material has been created by C.Lazzeroni and includes a set of "trump cards", that represents the known particles in the Standard Model [6] together with their charge, mass and favourite interactions (forbibben interactions are communicated to young pupils as "dislikes", allowed interactions are instead represented by "likes").

A typical Particle Physics session in the primary schools at IC Carvico starts with a motivation session connecting the sub-atomic world to the macroscopic world we live in, that is of course much more familiar to young pupils.

Once the notion of "atom" has been established, an inquiry-based approach is used in order to bring students to formulate the question: "What is inside the atom?" Then neutrons , protons and electrons are presented and eventually the wonderful zoo of elementary particles enters the scene. It is explored (in Italian) through the translated trump cards game, the concrete building of "your own particles" (coloured and decorated polystyrene spheres with properties that correspond to those of the particles they represent – for instance, heavier spheres are used for heavier particles and so on).

Finally, depending on the specific audience, some more advanced topics like Feynman diagrams can be introduced through the intuitive idea of 'story-telling', that can evolve at a later stage of the curriculum into some more mathematically precise representations of particle interactions.

In 2019 the Particle Physics for Primary Schools (PPPS) project evolved into a structured training program for teachers in collaboration with INFN - Sezione di Milano Bicocca. About 90 primary school teachers in the Bergamo area took part in a two-day workshop where the basics of the Standard Model and accelerator physics as well as an introduction to modern Cosmology were offered in academic lectures by S.Malvezzi, C.Lazzeroni and D.Binosi (ECT*, Trento, Italy). The lectures were supplemented by demonstrations by the teachers at IC Carvico, and addressed to their colleagues, on how to present the material of the PPPS program to their school pupils. In addition an evening session dedicated to parents was organized with a lecture by S. Malvezzi.

Despite the lockdown imposed by the SARS-CoV-2 pandemic, about ten of the participating schools succeeded in completing the PPPS activities in their schools, either in presence or at distance. The final results of the training program were presented in an online workshop held on November 2020.

3. Results

Several results have been achieved, that are summarized as follows.

- The interaction between professional researchers and (well-motivated) teachers is a key factor in ensuring the effectiveness of science-related teaching projects. Teachers have a huge background of competencies on how to teach in general and an invaluable feeling of "how to teach in particular" in their classes. Thus they can provide an extremely useful framework of structured programs in order to obtain a tailor-made solution for each specific class (and, ideally, each pupil). On the other hand, professional researchers play a crucial role in safeguarding the correctness of the information provided. The complexity of modern science does

not lend itself to simplifications or self-study. As Einstein used to say, things should be presented as simple as possible, but not simpler. Therefore a thorough preliminary study of the subject under the supervision of professional researchers is a pre-requisite, as well as a constant supervision of the teaching activities by the same reasearchers with respect to the methodology and the scientific results concerned. It should be noticed that this kind of interplay is also beneficial to the transmission of the social and cultural nature of science, with its own methods and social shared values that have to be faithfully presented to the younger generations, as has been pointed out by E.Birr-Moje in [7].

- Early exposure to the science of Particle Physics enhances the appreciation of the subject and science as a whole as an interesting option to be pursued in higher education. Moreover the question: "Which career path should I follow when I grow up?" can receive much wider and better-motivated answers in young pupils who have a feeling about what science is and how exciting it can be. This holds in particular for pupils coming from social and culturally disadvantaged backgrounds.
- Follow-up surveys filled in by pupils at the end of the project (about 50 pupils per year starting from 2017) show on average an increased motivation about studying science, with no significant gender-related bias.

4. Discussion

Based on the results obtained both in the classes and during the teacher training program in 2019, we conclude that the PPPS program meet some deeply rooted teaching needs. Its positive impact on students has been firmly established.

The pedagogical foundations of the approach however need to be further explored, in order to test whether the proposed approach can be applied to a more general setting and to different physics subjects other than Particle Physics.

In this context we mention that the results of the PPPS project have been presented at a nation-wide conference organized by INFN [8]. This conference sparkled some interest from several INFN Sections, in particular in Turin. A joint work to present a comprehensive approach to the teaching of contemporary physics, including both Particle Physics and General Relativity, is currently under discussion with the INFN Turin group and the University of Turin.

5. Conclusions

The teaching of science in today's schools must face, amongst others, two specific challenges: the first is the need to build and maintain a bridge between cutting-edge research and outreach activities geared towards teachers; the second is the required interdisciplinary effort, involving both teachers and professional researchers, in shaping learning materials, learning practices and teaching strategies capable of guaranteeing the quality and reliability of scientific information as well as the effectiveness of the pedagogical transposition. In this endevour we recognize some aspects that seem specific to the XXI century: the rapid obsolescence of textbooks (often deemed insufficient by teachers and experts in contemporary learning sciences), to be accompanied by learning materials authored by research institutes and universities; and the outreach benefits for research institites and universities in reaching a vast audience potentially including students and parents, fulfilling their civic duty. We believe that the PPPS program provides some hints on how both challenges can be addressed.

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Data Availability Statement: In this section, please provide details regarding where data supporting reported results can be found, including links to publicly archived datasets analyzed or generated during the study. Please refer to suggested Data Availability Statements in section "MDPI Research Data Policies" at https://www.mdpi.com/ethics. You might choose to exclude this statement if the study did not report any data.

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Abbreviations

The following abbreviations are used in this manuscript:
PPPS: Particle Physics for Primary Schools

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