Particle Physics for Primary Schools: a Case Study about Science Teaching in K-12 Schools

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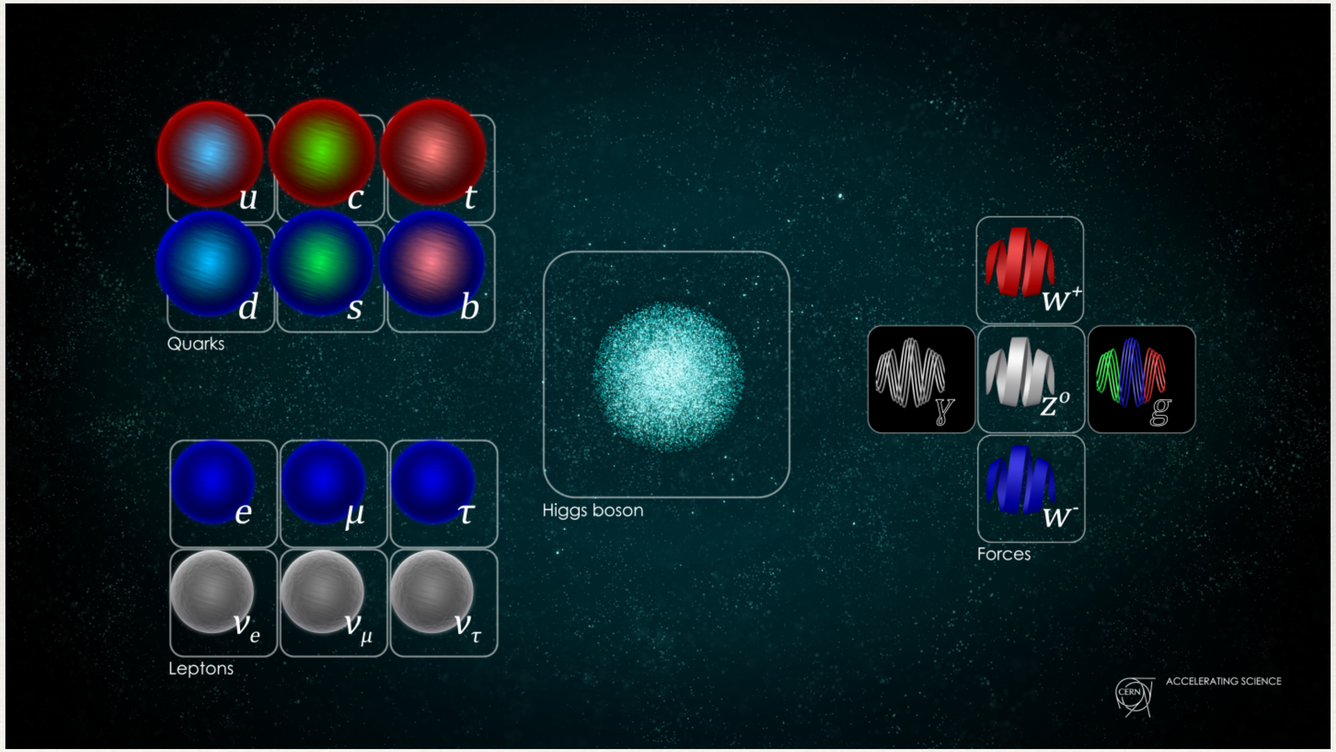
The Standard Model of Particle Physics

The Standard Model (SM) of Particle Physics is a cornerstone of contemporary physics, whose last experimentally verified prediction is the Higgs boson resonance discovered at the LHC in 2012.



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Disseminating Science and its Values

Teaching the SM in schools is an opportunity with many benefits:

- pupils are exposed to the methodology and the values of science (scientific rigour, passion for new discoveries, the beautiful endeavour of extending human knowledge beyond what we know today);

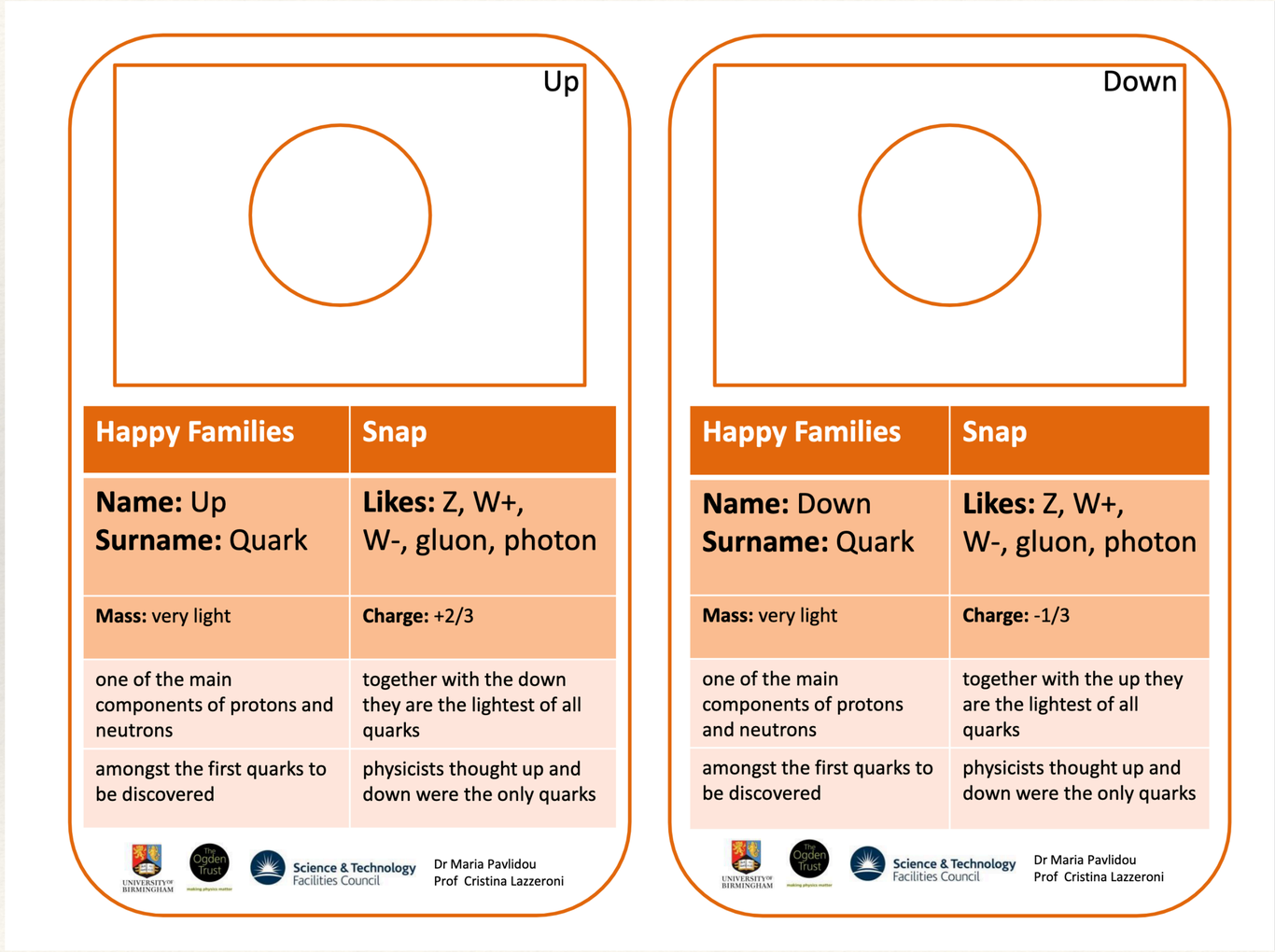
- early exposure to science can foster the willingness to pursue a scientific career (children often imagine what they will do when they grow up at an early age, and especially for those coming from a poor social background the opportunity to think about science is not so common unless they have the chance to learn about it in school);

- the SM embodies an experimentally verified knowledge that is not so widespread in current textbooks and learning material for K-12 schools.

Particle Physics for Primary Schools - the UK format

- The Particle Physics for Primary Schools (PPPS) program has been originally developed by C.Lazzeroni and M.Pavlidou (University of Birmingham, UK) in 2015.
- The goal was to create meaningful interactions and engagement between scientists, teachers, and students at the early stage of their educational journey, around modern cutting-edge science and its beauty and open questions.
- The workshop firstly developed as a school or after-school or enrichment activity, to be performed in a period of about 3 h. It was held by researchers as experts in the field.
- The workshop has been delivered to a number of local schools in the West Midlands region in the UK, between 2015 and 2018.
- A set of practical resources, including learning material, lists of items for the art-and-craft activities and a comprehensive teacher manual, has been developed and used in teacher and educators development (CPD) courses organized by several institutions (Institute of Physics, Odgen Trust, CERN, STEM Ambassadors among others).

Trump Cards


Up
Happy Families
Snap
Name: Up
Surname: Quark
Likes: Z, W+, W-, gluon, photon
Mass: very light
Charge: +2/3
one of the main components of protons and neutrons
together with the down they are the lightest of all quarks
amongst the first quarks to be discovered
physicists thought up and down were the only quarks
Science & Technology Facilities Council
Dr Maria Pavlidou
Prof Cristina Lazzeroni
Down
Happy Families
Snap
Name: Down
Surname: Quark
Likes: Z, W+, W-, gluon, photon
Mass: very light
Charge: -1/3
one of the main components of protons and neutrons
together with the up they are the lightest of all quarks
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Prof Cristina Lazzeroni

Particle Physics for Primary Schools - the Italian format

- More emphasis on the teachers' training.
- Researchers train the teachers, the teachers present the material to pupils and then get a feed-back from researchers.
- Implemented in several schools in Northern Italy since 2017, first in Carvico and then in various schools in the Bergamo area.
- 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 devoted to the basics of the Standard Model and accelerator physics by researchers in the field and to the demonstrations by the teachers aimed at the teachers of the set of teaching activities and materials of the PPPS program.
- Feed-back from teachers to researchers on the effectiveness of the material and on improving the learning strategies.

Short description of the Italian PPPS workshop

- Grade 4-5 classes (pupils are 8-10 years old).
- The activities last from 15 days to one month (the program is offered at different levels of details, connections with atomic physics and chemistry may or may not be presented depending on the classes), on the average two hours a week.
- The introductory part is always about motivation.
- Most appreciated activities: Trump Cards, Build your own particle, Models of molecules and atoms.
- Peer learning and collaborative work are strongly encouraged by teachers and widely used in classes.
- Some online extensions developed due to the COVID-19 pandemics and related restrictions.

Main results

- The interaction between professional researchers and (well-motivated) teachers is a key factor in ensuring the effectiveness of science-related teaching projects.
- Early exposure to science and specifically to Particle Physics enhances the appreciation of the subject and science as a whole as an interesting option to be pursued in higher education.
- 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.
- Companion outreach activities dedicated to parents are also foreseen (public lectures on the SM).

Distributing and Updating Science Teaching Resources

- Need of trustworthy and accessible information, especially that designed to support education.
- Research agencies and universities are key players in the process of disseminating knowledge to young pupils in schools.
- Digital Learning Objects distributed under Creative Commons licenses to foster their dissemination and reuse.

Outlook

- Based on the results obtained both in the UK and the Italian programs, we conclude that the PPPS program meets some deeply rooted teaching needs.
- The substantial difference in the school system of the two countries adds confidence that the positive results obtained are significant and could be generalized to a different educational context.
- The pedagogical foundations of the approach also need to be further explored (pedagogical assessment of key competences acquired, some interest in possible applications of the PPPS project to prospective teachers' training programs at undergraduate level).

References

- The PPPS workshop at the University of Birmingham:

  https://www.birmingham.ac.uk/schools/physics/outreach/primary-schools/particle-physics-workshop.aspx

- C. Lazzeroni, S. Malvezzi, A. Quadri, Teaching Science in Today's Society: The Case of Particle Physics for Primary Schools, Universe 2021, 7(6), 169; https://doi.org/10.3390/universe7060169 and references therein