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Colloquia: CooFIS08 2024 Researches

Preface

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This volume collects twelve papers selected with international peer review among those presented and discussed at the third Meeting of CooFIS08, held in Cagliari in November 2024. CooFIS08 is the community of Italian professors and researchers institutionally framed and/or institutionally qualified for the physics education research and for the history of physics research of the current scientific disciplinary sector PHYS/06-B, who have decided to cooperate in the field of such research.

CooFIS08 was founded in September 2022 in Milan, and among its various activities it has an annual meeting for the presentation, comparison and discussion of the research taking place in the 18 different research units. The first CooFIS08 Meeting was held in Udine in November 2022 and the main contributions are published in *Il Nuovo Cimento* [1]. The second was held in Naples and produced a volume of selected papers published by Springer [2]. The third, held in Cagliari, focused on physics education: from frontiers of research in physics to the diffusion of scientific culture, opening with two sessions dedicated respectively to research-based teacher education and the dissemination of scientific culture with the contribution of research institutions.

The meeting was organized under the title "Improving the teaching of physics: from research in physics education and history of physics to activities in schools and universities". Its purpose was to reflect on the ways in which research can contribute to the improvement of physics education across different contexts: schools, universities, and teacher education.

Italian Physics Education Research (PER) has earned recognition at the international level, through contributions to indexed journals, participation in European projects, and the involvement of many groups in global networks such as GIREP, ESERA, EPS-PED, and MPTL. Yet, despite this vitality, national structural support remains scarce. Initiatives such as CooFIS08 therefore play a dual role: they are scientific gatherings where results are presented and debated, but they also serve as community-building events that strengthen the disciplinary identity of PHYS/06-B and reaffirm its contribution to the broader physics community.

The twelve contributions are organized into thematic sections that reflect the richness and diversity of research lines pursued in Italy.

Conceptual change. The opening paper, *e^4 higher Educational tools for an Embodied and creative Education on Energy*, presents the results of the Erasmus+ project coordinated by the University of Bolzano. The project develops embodied approaches

to conceptual change in the teaching of energy, using storytelling, "Forces of Nature Theater", and LEGO® Serious Play. It provides a structured and validated framework for supporting teacher professional development, with strong implications for conceptual change in the understanding of energy.

Informal learning. Three contributions highlight how non-formal and interdisciplinary perspectives can enrich physics education. The national Draw a Person Doing Science survey investigates prospective primary teachers' representations of scientists, revealing gender imbalances, stereotypical features, and the absence of digital tools. The Cagliari group proposes a teaching-learning sequence on gravitational physics, inspired by the Einstein Telescope project, where natural language and debates on scientific controversies play a central role in connecting students' discourse with the epistemology of science. The Trento group focuses on climate education, developing a teaching-learning sequence based on expert interviews and testing it in multiple schools, documenting both conceptual gains and differentiated profiles of student engagement with climate change.

Formal learning in secondary schools. The Udine group examines students' interpretative perspectives on thermal phenomena and the meaning of equilibrium in static and dynamic conditions, as a basis for the acquisition of scientific awareness in the goals of daily energy saving. Through real-time laboratory explorations, they show how the concept of temperature as a state property can emerge, promoting a shift from common sense and daily or calorimetric views towards a more coherent thermodynamic interpretation by states and processes.

Experiments in physics. Two contributions emphasize the central role of experimental practice. One, developed by researchers of Milan University, concerning an educational activity on internal gravity waves in stratified fluids enables students to access an advanced phenomenon that is central in geophysics and climate studies but difficult to observe in the laboratory. Another one, developed by researchers of Salerno University focuses on sunlight trapping: the authors introduce the concept from a physics perspective and propose creative educational applications that stimulate both scientific understanding and the imagination of sustainable solutions.

Learning in physics. A large-scale investigation by the Udine group explores high school students' reasoning on electromagnetic waves. Analysis of nearly 200 questionnaires reveals common misconceptions about wave profiles, frequency, and propagation, offering insights into how learning difficulties are interrelated and how teaching strategies might address them.

Formal learning at university. An interdisciplinary thesis model designed for engineering programs was presented by researchers of Palermo University. This initiative integrates physics knowledge with applied engineering contexts, enhancing students' conceptual understanding, critical thinking, and professional readiness, and providing a structured opportunity to consolidate physics learning at the university level.

History of physics in physics education. The final three contributions emphasize the didactic potential of historical perspectives. Researchers of Milan University analyze Thomson's atomic model, showing how the "plum pudding" caricature widely propagated in textbooks obscures the original conceptual framework and generates enduring misconceptions. A contribution from researchers of Genova, Turin, and Verona Universities deals with the historical reconstruction of Wilson cloud chamber, from its origins in meteorology to its role in nuclear and particle physics, and advocates for its use in teaching the nature of science in schools. A further contribution from Genova and Rome Universities concludes with an account of Ettore Majorana's degree thesis, situating it in the scientific debates of the 1920s and highlighting its significance as a historical and didactic source.

Taken together, the contributions in this volume illustrate the breadth of Italian research in physics education and history of physics. They address fundamental issues such as conceptual change, the integration of informal and formal learning, the role of experiments in making physics accessible, the persistent difficulties of students in key domains, research strategies for the construction of educational paths useful for teaching, and the importance of history and epistemology for understanding science as a human enterprise.

The Cagliari meeting also demonstrated the strength of the CooFIS08 community, where early-career and established researchers collaborate across institutions, schools, and disciplinary boundaries. By presenting these contributions, we aim to provide both a resource for practitioners and an inspiration for further research, reinforcing the role of physics education research and history of physics research within the national and international physics landscape. We therefore hope that this work will be useful to colleagues and teachers in their work.

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