

4th World Conference on Physics Education



BOOK OF EXTENDED ABSTRACTS

EMBRACING CHANGES TOGETHER

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JAGIELLONIAN UNIVERSITY
IN KRAKÓW

Faculty of Physics, Astronomy and Applied Computer Science



Uniwersytet
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4th World Conference on Physics Education



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EMBRACING CHANGES TOGETHER

Book of Extended Abstracts

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Embracing Changes Together

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Mirela Kaczmarek
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INVITED TALKS

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Enhancing Physics Education through Dimensions of Learning: Examples from Research

Claudio FAZIO

University of Palermo, Italy



Claudio Fazio got his Master Degree in Experimental Physics at the University of Palermo (UniPA), Italy, and his PhD in Physics Education Theory at the University of Bratislava, Slovakia. He is full professor in Physics Education and History of Physics at UniPA and teaches Physics Education and History of Physics at the degree course in Physics, and General Physics and Physics Education at the degree course in Primary School Teacher Education of UniPA. He is vice-president of GIREP, national coordinator of the Italian Plan for Scientific Degrees - Physics, and dean of the doctoral program in Technologies and Methods for University Education of UniPA. He has been and is currently responsible of international research project in the field of science and mathematics education. Author of more than 140 papers published in international and national scientific journals and books, his current areas of research focus on: implementation and validation of active learning methodologies in STEM Education; study of the psycho-pedagogical foundations and dimensions of active learning methodologies applied to STEM education; use of technologies in Physics laboratory; use of modelling environments for learning; use of qualitative and quantitative analysis methods in STEM Education Research.

Invited talk: Overview & Highlights

One of the main aims of education research is to foster effective learning of new knowledge, concepts and methods. In these last years, there has been a growing interest in the educational community in specifying and clarifying the different aspects of the learning processes that can help teachers and researchers to offer students a multifaceted approach to the construction of their knowledge, and physics education is no exception in this. By addressing cognitive, affective, and metacognitive aspects of learning, physics educators can create enriching experiences that empower students to become lifelong learners and proficient problem-solvers in physics.

Frameworks have been developed by educational researchers that focus on the idea that specifying the "dimensions" of learning, educators can create dynamic learning environments that cater to diverse student needs and promote holistic understanding. Dimensions of learning, like the development of attitudes and perceptions, learning styles, acquisition and organization of knowledge, critical thinking, metacognitive thinking have been studied, aiming to improve student appropriation of subject matter and engagement in study and exploration.

In this talk I will discuss some relevant aspects of these frameworks, and I will present a conceptual map, developed during a research on learning the physics related to surface phenomena in liquids with high school students, that makes explicit the dimensions of learning that we wanted to study at that schooling level. I will show how highlighting these dimensions can allow the teachers and researchers to consciously construct teaching activities and study their efficacy, also by selecting appropriate methods of data collection and analysis.

Digital Competences and Physics Education – A Rich Field for Classroom Practice and Teacher Education

Andreas MUELLER

University of Geneva, Switzerland



Andreas Mueller is a professor of science education at the University of Geneva/CH, on a joint appointment of the institute for teacher education (Institut de Formation des Enseignants, IUFÉ) and the Faculty of Science/Physics Section. His current interests in research and development are twofold: empirical investigations and research based development in science education, in particular about context orientation and about the role of tasks and exercises for effective learning and teaching; science of everyday phenomena, cross-disciplinary connections of physics with the other sciences, hands-on-experiments. In both areas, the use of smartphones and other mobile devices has had a central place in his work in recent years. In physics teacher education, his main goal is to establish a good synthesis of good practice of experienced and innovative teachers on the one hand, and the large body of research-based knowledge about teaching and learning available nowadays on the other hand..

Invited talk: Overview & Highlights

Recent research and development efforts utilizing smartphones and tablet computers for physics education will be reviewed, with a focus on intended competencies and other educational objectives.

Building on empirical outcomes and the current discussion on multimedia and other digital tools for educational purposes, various promising avenues for classroom instruction and teacher training will be proposed for further discussion. As an outlook, some related aspects of artificial intelligence in the physics classroom will be included to provide a broader perspective.

Teacher Professional Development in Transformative Times: Three Collaborative Visions for the Future of Physics Education

Magdalena KERSTING

University of Copenhagen, Denmark



Magdalena Kersting is an assistant professor of science education at the University of Copenhagen. With a background in physics, mathematics, and science communication, she holds a Ph.D. in Physics Education Research from the University of Oslo and is a recipient of the International Astronomical Union Ph.D. Prize. She is the main editor of "Teaching Einsteinian Physics in Schools" and co-founder of the International Modern Physics & Research in Education Seminar Series (IMPRESS). Her interdisciplinary research intersects physics education, embodied cognition, and technology perspectives, with a key emphasis on how embodied experiences shape scientific understanding. Beyond physics, her work extends into broader STEM disciplines, including teacher education, and investigates the educational possibilities of tools like virtual reality and artificial intelligence.

Invited talk: Overview & Highlights

Physics education today unfolds against a backdrop of rapid societal transformations. Climate change, geopolitical crises, and quickly evolving technologies outstrip the pace of curriculum development, calling for a re-evaluation of educational practices. In line with the overarching conference theme "Embracing Changes Together", this talk presents three collaborative visions for the future of physics education that attempt such a re-evaluation. My common anchor for these visions is the focus on teacher professional development since preparing and supporting physics teachers is key to transforming educational practices. The first vision promotes interdisciplinary collaboration, merging cognitive science with physics education. The Science Education Network for Supporting Embodied Sense-Making (SENSES) serves as an example of high-school teachers co-creating instructional resources inspired by embodied cognition principles to make physics more accessible to a broader range of students. The second vision advocates for collaborative dialogues between teachers and research physicists. The Danish cross-institutional STEM master programme (KASTEM) illustrates how such collaboration can empower teachers to work alongside climate and space physicists, co-developing innovative, inquiry-based pedagogies that bridge cutting-edge science with primary and middle school curricula. The third vision embraces the collaborative potential of generative artificial intelligence (GenAI). By treating GenAI not as a mere tool but as a non-human co-creator and collaborator in the learning process, we can explore synergies between embodied minds and disembodied machines, thereby shifting our understanding of the role of the teacher and what physics learning means in the first place. To conclude, these visions call on the physics education community to embrace change collaboratively, pooling insights across fields, professions, and technologies to support teachers and advance learning.

Cultivating a Feeling for Physics: The Importance of Epistemic Empathy and Responsive Teaching

Lama JABER

Florida State University, United States of America



Lama Jaber is an Associate Professor of Science Education in the School of Teacher Education at Florida State University. Before earning her doctorate in science education at Tufts University, she started her career as a middle and high school science teacher. Dr. Jaber's research examines learners' disciplinary engagement in science, with particular attention to learners' feelings and emotions within that engagement, both in face-to-face and online learning environments. She also studies how teachers promote learners' engagement through responsive teaching practices and examines the role of teachers' empathy in that process. Her current research is

funded by a National Science Foundation CAREER grant that has served as the main context for her recent work on epistemic empathy. Her research has been recognized through an Early Career Research Award from the National Association for Research in Science Teaching.

Invited talk: Overview & Highlights

When learners sense that their cultural, experiential, emotional, and other sensemaking repertoires are not relevant to their physics learning, they may come to perceive physics as inaccessible to them. This, in turn, creates barriers to their engagement, barriers that are particularly consequential for students from historically marginalized populations in physics. Therefore, there is a pressing need to design physics learning environments that make room for and are responsive to students' varied experiences, emotions, and other funds of knowledge. My work aims to address this need by examining ways to support teachers in this work through cultivating epistemic empathy—the capacity for tuning into and appreciating learners' intellectual and emotional experiences within epistemic work—and exploring how such empathy can promote responsiveness to students' experiences and contributions in the classroom. In this talk, I describe how I came to conceptualize epistemic empathy as a target for teacher learning and discuss possible ways to cultivate such empathy in teacher education, outlining tensions that emerge within this work. My hope is to generate a discussion about the role of empathy in teaching and learning, and how such empathy can be channeled to promote strength-based and dignity-affirming learning spaces that honor and cultivate learners' experiences and feelings in physics.

What I've Learned in 48 Years of Research in Physics Education (PER)

Marisa MICHELINI

University of Udine, Italy



Marisa Michelini is Senior Full Professor of Physics Education in the University of Udine, Italy, where she was Rector Delegate (1994-2019), Head of Physics Department (2004-2010) and of the Specialization School for Secondary School Teachers (2003-2008). She is scientific president of GEO university consortium for young, education and guidance and president of Italian Physics Education and History of Physics Community. She was head of the projects IDIFO series under the 'Scientific Degrees Project' (PLS) carried out from 2006 till 2022, involving 20 other universities on Innovation in Physics Education and guidance on modern physics, heading 6 biannual national Master for teacher education, 8 full immersion summer school for talent students and 4 full immersion teacher education school at national level. At international level she was president of GIREP (2012-2023), board member of EPS-PED (2016-2024), of MPTL (2024-2022). She carried out research on electrical transport properties of different materials (1985-1992) and PER for all life, leading 2 EU projects and being responsible for Italy in 7 EU projects, 18 Italian and 8 regional projects. She received the awards of the Italian Physical Society for Didactic (1989) and the IUPAP-ICPE international medal award for the research in physics education (2018). Research activity is documented by 680 peer review selected publications in books or journals.

Invited talk: Overview & Highlights

After experimenting different research methodologies in the framework of content research for the development of vertical conceptual paths, it emerged that the Entangled Research Lines (ERL) method offers the opportunity to finalize the need to integrate study on fundamental concepts, on strategy for learning environment, on conceptual change processes, on the role of ICT for learning and research and development of prototype for experiments and teacher education. Evidence based results collected by different modules of formative intervention in iterative way and in different context offer the opportunity to develop strategies for active learning, for building formal thinking and physics identity. Specific researches produce the MEDS model for initial teacher education and strategies that are still being tested for in-service teachers. ERL model will presented with evidence based results.

Does How We Teach Match How Students Learn? The Evolving Relationships Among Theory, Experiment, and Teaching Practice in PER

Paula R. L. HERON

University of Washington, United States of America



Paula Heron is a Professor of Physics at the University of Washington. She holds a Ph.D. in physics from the University of Western Ontario. Dr. Heron's research focuses on the development of conceptual understanding and reasoning skills. Dr. Heron is co-Founder and co-Chair of the biannual "Foundations and Frontiers in Physics Education Research" conference series, the premier North American venue for physics education researchers. She has held leadership roles in the American Physical Society (APS), the American Association of Physics Teachers (AAPT), and the European Physics Education Research Group (GIREP) and also serves as an Associate Editor of *Physical Review – PER*. She co-edited the first *International Handbook on Physics Education Research* (AIP, 2023). She is a Fellow of the APS, a co-recipient of the APS Education award, and recipient of the Homer Dodge Citation for Outstanding Service to the AAPT.

Invited talk: Overview & Highlights

One of the earliest and most influential insights of PER is that closely examining student thinking (as opposed to, for example, closely examining the content we teach) can propel advances in teaching. Whether these advances in teaching were attributed more to new(ish) theories of learning, or more to empirically-founded guidance, it is clear that simply listening to students and taking their ideas seriously represented a revolutionary change in physics teaching. In this talk I will revisit these early years and trace some developments that suggest we may be on the threshold of another significant change; albeit perhaps not as dramatic as that of the 1980s and 1990s. Specifically, I argue that in early years of PER, theories of learning, and hence theories of teaching, were extrapolated from data acquired by asking learners to answer questions. The content of their answers, and any regularities observed over variations in the circumstances in which the questions were asked, as well as variations in the questions themselves, were used to draw inferences about the nature of learners' knowledge: what it consists of, how it is organized, and how it was obtained. These in turn were used to draw further inferences about how learners' knowledge could be changed. Validation rested primarily on whether changes were observed in how students answered those same questions. These sets of inferences constitute a few linked theories: a theory of in-the-moment answering, a theory of spontaneous learning, a theory of planned learning, and a theory of teaching. I argue that the process of producing an answer to a question, and the process of learning, which leads to a change in the answers produced in response to such questions, while undoubtedly related, are different. Relatively little effort has been invested in our field in examining each of these theories, and the links among them. However, the experimental techniques we employ have been growing in precision and sophistication, as have the theoretical propositions. Therefore I argue that we, as a field, are now in a position to develop a broader, more coherent, more empirically supported, and more powerful framework to guide physics education so that how we teach more closely matches how students learn.

Climate Change in Physics Education: Why, What and How?

Thomas SCHUBATZKY

University of Innsbruck, Austria



Thomas Schubatzky is an Assistant Professor for Physics Education and Head of the Unit of Math and Science Education at the University of Innsbruck. His research interests revolve around climate change education, educational technology and media literacy in science education and science teacher education. His work has been published in various international journals, including *Computers & Education* and *Science Education*. He is also active in projects at the European level such as ENGAGING, in teacher professional development and is a guest editor of a German-speaking physics teacher journal.

Invited talk: Overview & Highlights

With the world facing unprecedented environmental challenges due to climate change, it is vital for physics educators to support students in developing knowledge, attitudes, and skills to address these pressing issues. However, climate change represents not just a scientific phenomenon but a multidimensional challenge with profound societal, economic, and ethical implications. By integrating climate change into physics education, we not only enhance students' understanding of climate science but also foster their capacity for informed decision-making and responsible citizenship in a rapidly changing world.

In the talk, I will try to shed light on different dimensions of climate change education and discuss recommendations for learning settings revolving around the status of climate change education research. First, I will highlight the state of students' understanding of fundamental physics principles underlying climate phenomena and ways to address them. Then, I will argue how we can support students to assess scientifically credible information about climate, therefore developing resistance to climate science denial or misinformation. Furthermore, I will talk about the role of emotions in when it comes to discussing about climate change in class. To sum up, by integrating climate change and discussions on equity, justice, and sustainability into the physics curriculum, educators can promote values of empathy and global citizenship, inspiring students to become informed citizens.

Active In-Service Training on Transversal Skills: Two Pilot Cases in STEM Disciplinary Teaching

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Abstract. Promoting gender equality in STEM disciplinary teaching and self-assessment skills in students requires transversal competences and methodologies that are usually not included in teachers' cultural background. Based on previous experiences, we implemented, in an interdisciplinary team, two in-service training courses for teachers. In one, after introducing the topic of gender and related educational issues, teachers were invited to develop a learning path to be implemented in class in the following months. Then we analysed together the results and critical issues that emerged. In the other, a laboratory of self-assessment for students is promoted by an in-service course for STEM teachers

Introduction

Transversal competences' learning, while being critical to future professional success, is not an easy or straightforward process [1]. It involves various stakeholders, with a particular focus on students and teachers. It should be explained and participatory, including formal learning, but also non-formal and informal learning, in an integral logic of acquiring and developing competences.

Two pilot experiences were conducted to address issues that have emerged in recent years in our territories, specifically southern Tuscany. These issues include a decrease in the number of girls interested in physics studies and a decline in scientific skills among students entering scientific degree courses.

Active In-Service Training for promoting gender parity in STEM

Despite being one of the Sustainable Development Goals, achieving gender equality and empowering all women and girls by 2030 is not on track [2]. The underrepresentation of women in science, technology, engineering, and mathematics (STEM) fields is a well-documented issue in developed countries. However, current actions to overcome gender disparities in STEM are far from satisfactory. Courses in biology or mathematics often have a predominantly female gender distribution, which presents the opposite issue. This phenomenon is influenced by pre-existing biases and reinforced by experiences in high school.

Improving transversal professional skills is crucial for science teachers to identify their own and their students' biases, the mechanisms that reinforce them, and the positive actions in disciplinary teaching practice that can weaken them through positive experiences in the scientific field.

The development of an in-service training course for teachers last year was a successful project in this direction. The provincial school office, in collaboration with the University of Siena and the University for Foreigners of Siena, organized the course for teachers from every school level in the province of Siena. The course was divided into two parts, with the first one focusing on addressing issues related to inclusion. It provided active tools [3] for recognizing prejudice and discrimination to all teachers. In the second part, teachers followed separate modules in homogeneous groups based on school level and disciplinary macro areas. The module aimed at high school teachers in the STEM area was expertly coordinated by one of the authors (VM), who

involved the other author in some activities. As a result of the participants' requests, it was decided to continue with a course for high school teachers. The results of the latest course, which had 20 participants, are presented. The course included activities that were concentrated at the beginning of the school year and lasted for 16 hours. Each participant then designed and implemented a learning path in the following months, taking into account gender discrimination in disciplinary activities. A focus group will discuss the experiences gained by the end of the school year.

Self-evaluation laboratory in STEM: a pilot case

Prior knowledge is essential for success in STEM courses at university and is usually tested in entrance exams. One of the actions of the National Plan for Scientific Degrees is dedicated to improving these initial skills.

In 2020, the PLS-Biology, PLS-Chemistry, and PLS-Natural and Environmental Sciences promoted an activity aimed at improving the scientific skills necessary to pass the respective tests. The interdisciplinary group of the Sienese PLS proposed a self-evaluation laboratory for the high schools of southern Tuscany, which included all the scientific disciplines involved in university entrance tests.

The laboratory is designed for STEM teachers who can enrol one or more classes, preferably in the third or fourth year of the high school course). The first step is an entrance test provided to teachers, who will decide which disciplines and topics can be addressed by their students, administered in the same ways and times as those foreseen by the tests administered in Italy almost exclusively through a portal online managed by an inter-university consortium (CISIA). Teachers correct the tests and identify critical issues in the teaching of certain disciplinary topics in the results. Addressing these critical issues through a short course dedicated to professional development allows teachers to plan and implement educational interventions aimed at overcoming them. The effectiveness of the intervention will be evaluated based on the results obtained by the students in one of the tests on the OrientAzione portal [4] (an online resource was developed in the PLS to support these actions).

There are 8 schools registered in the laboratory, with 25 classes followed by 36 teachers, 18 science teachers, and 18 mathematics and physics teachers.

We present the materials provided to the participants as examples of possible teaching tools to be used in the classroom and the critical analysis of the results obtained after the teachers' elaboration and implementation in their teaching context.

References

- [1] M. J. Sá and S. Serpa, Transversal competencies: Their importance and learning processes by higher education students, *Educ. Sci.* **8** (2018) 126-137 doi:10.3390/educsci8030126.
- [2] <https://unstats.un.org/sdgs/report/2022/goal-05/>
- [3] A. R. Pandea, D. Grzemny and E. Keen. *Gender matters: a manual on addressing gender-based violence affecting young people*, 32-42, Council of Europe, Budapest, 2020.
- [4] <https://www.orientazione.it/>