82nd International Scientific Conference of the University of Latvia 2024

Section

PHYSICS. EDUCATION. PRACTICE.
Seminar for University Physics Education Practitioners

Abstract Book

UNIVERSITY OF LATVIA

Faculty of Physics, Mathematics and Optometry
Department of Physics

Chair of Physics Education Research

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82nd International Scientific Conference of the University of Latvia 2024

FIZIKA. IZGLĪTĪBA. PRAKSE. Augstskolu fizikas izglītības praktiķu seminārs

PHYSICS. EDUCATION. PRACTICE. Seminar for University Physics Education Practitioners

Wednesday, 31 **January 2024, 10.00 AM**,
Zoom link: https://ej.uz/PhysEdPract2024

Programma/Programme

Vadītāji/Chairs: Ludmila Belogrudova, Inese Dudareva		
10.00 - 10.05	***Ludmila Belogrudova*** *Faculty of Physics, Mathematics and optometry, University of Latvia*	**Atklāšana** **Opening**
10.05 - 10.35	***Jeff Wiener*** *CERN, Switzerland*	**Iespējas un izaicinājumi, iepazīstinot vidusskolēnus ar moderno fiziku: daļiņu fizikā gūtās atziņas** **Opportunities and challenges of introducing high-school students to modern physics: lessons learned from particle physics**
10.35 - 11.05	***Matthew Verdon*** *Australian Science and Mathematics School, Australia*	**Starpdisciplinārs darbs: matemātika un fizika vidusskolā un augstskolā – krustošanas punkts** **Interdisciplinary work around maths and physics in the secondary and tertiary crossover point**
11.05 - 11.45	***Emily Quinty*** *The University of Colorado Boulder, United States*	**Kā veicināt ekspertu prasmi mācīties?** **Cultivating Expert Learners, Not Just Expert Knowers**
11.45 - 12.00	**Kafijas pauze, diskusijas/Coffee break, discussions**	
12.00 - 12.30	***Janis Priede, Sandris Lacis*** *University of Latvia, Latvia*	**Par punktveida dipolu singularitātēm** **On the singularities of point dipoles**

12.30 - 12.50	***Juris Blūms*** *Riga Technical University, Latvia*	**Vidusskolas padziļinātais kurss Fizika II universitātē – pirmā gada pieredze un secinājumi** **High School Advanced Course Physics II at University - first year experience and conclusions**
12.50 - 13.05	***Didzis Lauva, Jevgenijs Proskurins*** *Riga Stradins University, Latvia*	**Tinkercad kā palīgs fizikas pamatprincipu apgūšanai** **Tinkercad as an assistant for learning the essentials of Physics**
13.05 - 13.20	***Jelena Kosmaca, Ilva Cinite, Girts Barinovs,*** *University of Latvia, Latvia*	**Bakalaura līmeņa fizikas laboratorijas darbu mērķu izpēte** **Exploring purposes in undergraduate level physics lab**
13.20 - 14.00	***Leo A. Siiman*** *University of Tartu, Estonia*	**Fizikas mācīšana ar izglītības tehnoloģiju palīdzību** **Teaching Physics with Educational Technology**
14.00 - …	**Noslēgums, diskusijas** **Conclusions, discussions**	

Opportunities and challenges of introducing high-school students to modern physics: lessons learned from particle physics

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Research has shown that 15-year-old students have a big interest in learning about space and astronomy, and discussing seemingly mysterious phenomena or phenomena scientists cannot explain yet [1]. Hence, modern physics has an immense potential for formal education in secondary schools. Indeed, one can assume that modern physics can spark students' interest and curiosity, improve their understanding of the nature of science, and bring them in contact with “real scientists” [2, 3, 4]. However, it can be challenging to bring the often abstract research questions and concepts into the classrooms and connect them to students' everyday lives. Moreover, teachers often lack the confidence to teach modern physics topics and need suitable educational resources linked to school curricula [5]. In this talk, we review the potential and challenges of modern physics education based on the research experience in CERN’s physics education team and discuss empirically validated teaching resources that have been developed at CERN over the past 10+ years to support teachers and bridge the gap between modern physics research, physics education research, and classroom practice [6, 7, 8].

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Cultivating Expert Learners, Not Just Expert Knowers

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PEER Physics, a curriculum-driven professional learning program developed by a team of high school teachers, university professors, and educational researchers at CU Boulder, promotes learning science by inducing scientific principles using the practices of science. Students spend the majority of class time conducting experiments, developing and revising models, supporting claims based on evidence, and coming to class consensus on key claims that account for all observations. Scientific principles are formalized, including disciplinary language and symbols, only after students make conceptual connections with day-to-day experiences and intuitive ideas. PEER Physics accomplishes this through a Learning Cycle (shown in Figure 1). Not surprisingly, student and teacher learning mirrors the process in which scientists learn—through active participation in inducing claims from data and collaborating to come to consensus on widely applicable principles from multiple experimental findings.

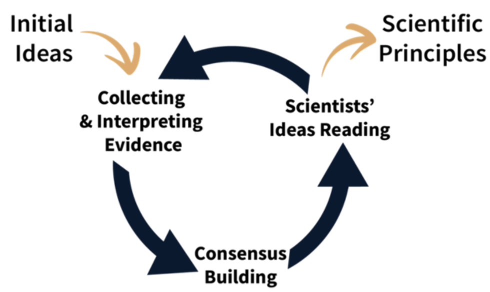

Figure 1. PEER Physics Learning Cycle.

For this learning to occur, it is essential to provide contexts in which learners can advocate for themselves through evidence in communities centered on becoming expert learners rather than just expert knowers. PEER Physics engages learners in a wide range of circumstances by appealing to their natural curiosity and desire to solve complex, accessible problems. This includes students and teachers as they generate principles about physics (students) or principles about teaching physics (teachers).

Lindsay, Belleau, and Otero (2018) found that on average, students in PEER Physics courses had learning gain scores 9.9% higher than students in traditional classes on an assessment of conceptual physics knowledge. The difference in gain scores between students in PEER Physics and traditional courses was statistically significant, with $t(332) = 5.7$, $p<.001$. Cohen's d for gain scores equaled 0.61, indicating a moderate treatment effect for students in PEER Physics courses. [1]

An independent study found that participation in the PEER Physics professional learning community resulted in greater learning gains in participating teachers' classrooms. Significantly, for each session attended by teachers, there was a 1.46% increase in learning gains among their students, after controlling for various potentially confounding teacher characteristics (Lindsay, Widman, and Garcia, 2019). [2]

In this session, videos of students engaging in the type of learning described above, and teachers grappling with ideas about teaching and learning science during a virtual professional learning session, will be discussed.

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On the singularities of point dipoles

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In this presentation, we offer an alternative approach to an old but still intriguing problem in classical electromagnetism that is encountered in most graduate-level physics and engineering courses. Following Jackson [3], it is commonly assumed that the expressions for the fields of electric and magnetic point dipoles, which the students have learned before, do not fully capture relevant properties of finite-size dipoles. In particular, it is argued that the symmetry of the point-dipole field results in a zero integral value over any spherical volume centered on the dipole. At the same time, finite-size dipoles have non-zero integral values. The correct integral value, which appears in the interaction energy of point dipoles, is essential for the agreement of quantum mechanical calculations of the hyperfine splitting in the ground state of hydrogen with experimental data [2]. This fact is used by Jackson [3] to justify ad hoc modification of the electric and magnetic point-dipole fields by adding terms with the Dirac delta function so that we have the correct integral values. Several subsequent mathematical approaches attempt to justify and formalise these modifications by introducing specific rules to find derivatives of Dirac delta functions [1]. All these approaches employ the so-called spherical regularisation, which is equivalent to postulating the integral of the point-dipole field over a spherical volume centred on the dipole to be zero. At the same time, when the corresponding integral is calculated using the unmodified expressions of the point-dipole fields, the angular part of the integral is indeed zero while the radial part diverges. Thus, the result is mathematically undermined rather than definitely zero as assumed before. We show that this indeterminacy is easily resolvable by using the irrotationality property of the electric field, which allows us to represent it as a gradient of electric potential, and the divergence theorem. This results in a rational and self-consistent representation of electric and magnetic dipole fields, which require no modifications.

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Advanced secondary school course Physics II in university - first year experience and conclusions

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In study year 2022-23 for the first time, RTU offered high school students to study the advanced course in Physics II - 5 contracts were signed with municipalities and 34 students from 7 schools started the course. During the implementation of the course, 3 students stopped their studies - it was too difficult. 6 out of 31 entered RTU this study year.

Providing secondary school students with advanced study course Physics II, 2023-24. m. g. the minimum required level of knowledge in the Physics I course has been increased (from grade 6 to 7), and in 2023-24 st.y. 44 students from 9 secondary schools study Physics II course at the RTU. 30 of them plan to take the physics state exam.

As an additional activity, based on the results of student surveys, at the beginning of the 2023-24 st.year, all 1st-year students had a physics prior knowledge test, and for those who had the proportion of correct answers below 50%, the study plan was supplemented by additional course (in the amount of 2 CP), which aims to refresh the knowledge of a high school physics course at the optimal level (Physics I). As the results show, it helped students who needed to refresh their knowledge, but was too short for those who did not have this knowledge. In the spring semester, it is planned to organize an additional study on the progress of the additional course graduates and to analyze the impact of the additional course on student dropout.

Tinkercad as an assistant for learning the essentials of Physics

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Tinkercad stands as a versatile ally in the pursuit of mastering Physics essentials, embodying a rich blend of STEM principles, spatial thinking, and programming. Beyond its conventional association with 3D design, Tinkercad offers a dynamic environment where students progressively engage with the intricacies of Physics.

As a learning assistant, Tinkercad provides a creative playground for students to initiate projects, cultivate synthesis skills, and address real-world challenges across the intersecting realms of 3D modeling, electronics, and programming. The platform uniquely combines the power of Codeblocks for animating 3D objects and a dedicated Circuits module, allowing a seamless integration of theoretical concepts with practical application.

In Tinkercad, users not only design and model but also set creations in motion using Codeblocks, necessitating an understanding of physics principles related to motion. The specialized Circuits module, particularly, centered around microcontroller codes, emerges as a direct link to physics education, offering a rich exploration of basic electricity, sensors, and actuators.

The platform becomes a facilitator for in-depth discussions on sensor functionalities and physical characteristics, acting as a catalyst for synthesis. Tinkercad encourages students to progress from using sensors as data loggers to defining thresholds and implementing reactions with actuators. This progression not only enhances physics essentials but also forges a robust connection to engineering.

The integration of logic boards to connect actuators and sensors introduces an information technology dimension, enabling students to read data on charts and debug schematics. Codeblocks, serving as both a 3D design tool and coding interface, provide an intuitive platform for dynamic model experimentation and understanding code intricacies.

Exemplifying an activity that showcases sensor programming, Tinkercad transforms projects into effective lessons, seminars, or workshops. Amidst alternatives, Tinkercad's unique ability to distill complex resources into an optimal STEM environment is noteworthy. Importantly, the platform's forgiving nature, allowing students to learn from mistakes without punitive measures, underlines its role as a supportive assistant, fostering an effective and enjoyable learning journey in mastering the essentials of Physics.

Exploring purposes in undergraduate level physics lab

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Our ambition is to transform the physics lab courses at University of Latvia to better align with the principles of modern physics education. We explore the purposes of physics labs in general, characterize current lab activities and discuss how labs could be improved based on lab instructor and student inputs.

A key challenge arises from the various goals of a physics lab, which teachers may define, from learning physics concepts to developing experimental, analytical, and collaborative skills. In contrast, students may perceive the lab as a tool to support their understanding of lecture material [1]. Physics education research suggests that labs can be more suited for learning experimental skills than theoretical concepts. Furthermore, scientific reasoning and interpersonal skills are increasingly emphasized as critical 21st century skills to be acquired in a physics class [2].

We discuss the progress in the transformation of our lab goals and formats based on interviews and surveys conducted among faculty members and students at the University of Latvia. Interviews with teachers highlighted the importance of visualization and data analysis as some of the main learning outcomes for an introductory physics lab. They also provided guidance on a more optimal lab course structure, agreed on the importance of aligning lab topics with lectures and described the organization of activities around a lab session. New ideas and concepts to test at the lab emerged, such as digital simulations, smartphone sensors, inquiry-based labs, and immersive experiences like escape rooms and project work. The Colorado Learning Attitudes about Science Survey for experimental physics [3] is used to assess the changes during the lab transformation.

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Teaching Physics with Educational Technology

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Educated in the United States with a BA in Computer & Electrical Engineering and a PhD in Laser Physics, my academic journey led me to an enriching career intersection of physics and educational technology. In 2013, I joined the educational technology research group at the University of Tartu, delving into the innovative ways technology can transform learning. My journey took a practical turn in 2019 when, in addition to my university duties, I began a part-time position at a local high school working as a physics teacher. Leveraging my unique background, I have been exploring the integration of educational technology into physics education.

Integrating technology into the physics classroom is a nuanced art that hinges on a profound understanding of pedagogy and an active engagement with students' cognitive frameworks. It's not merely about employing sophisticated tools, but rather about crafting a learning journey that resonates with the students' innate curiosity and comprehension patterns. Physics, inherently abstract and conceptually challenging, often leads students to construct personal, intuitive understandings that may deviate significantly from scientific realities. These misconceptions, if unaddressed, can form robust barriers to advanced learning, impeding the comprehension of more complex concepts built on foundational principles. In physics education research, the Force Concept Inventory [1] was one of the first instruments that revealed to me the importance of conceptual learning in physics. The physicist Eric Mazur recognized the importance of conceptual thinking in physics education and designed active learning strategies such as peer instruction to better promote conceptual knowledge [2]. He also employed clickers, now mobile phones, to get instant feedback and active participation from a large lecture room of students. Carl Wieman, a Nobel prize winning physicist, has employed computer simulations (https://phet.colorado.edu) in the classroom to encourage students to learn physics through game-like exploration [3].

Overall, my active involvement in education research, combined with my hands-on experience in the classroom, has afforded me a unique dual perspective, enriching my approach to teaching and adeptly prepared to incorporate emerging technologies like ChatGPT into the learning experience.

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About

The main organization of this section is done by the Chair of Physics Education Research of the University of Latvia. More information about our activities and research interests can be found on our website https://www.physedu.lu.lv/en/.

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