PTEE 2026

13th International Conference on Physics Teaching in Engineering Education

Book of abstracts

PTEE 2026

13th International Conference on Physics Teaching in Engineering Education

Faculty of Physics

Socratic Roots and AI Wings

27–29 May 2026

Warsaw University of Technology

Transforming Physics and Engineering Education

PTEE 2026 brings together a diverse community: staff of physics and science faculties, engineering educators, curricula and microcredentials developers, school teachers and educators, students and PhD candidates, cognitive scientists, and STEM education researchers.

This edition's theme, Socratic Roots and AI Wings – Transforming Physics and Engineering Education, invites participants to explore the fascinating intersection between time-tested dialogic teaching methods and the rapidly evolving landscape of AI-enhanced academic practice. It welcomes contributions that critically examine risk-aware, accountable, and evidence-based uses of AI in engineering physics education, while admiring the constant value of inquiry-driven learning.

The hosting institution, Warsaw University of Technology (Politechnika Warszawska, WUT), is one of Poland's most prestigious technical universities, founded in 1826. The rich history of innovation and excellence in engineering education makes it the perfect venue for PTEE 2026.

Date	Start Time	End Time	Session Type	A: Presentation Title	A: Presenter/Speaker/Authors	B: Presentation Title	B: Presenter/Speaker/Authors
27-05	**Wednesday**			Walking together to the Bolek Pub & Restaurant (optional), start at 17:30	*Meeting Point - Main Building of WUT*	*Politechniki 1 Square*	
27-05	18:00	19:00	Social Event	Welcome Social Event / Registration	*Bolek Pub & Restaurant*	*Niepodległości 211 Avenue*	*https://bolekpub.waw.pl/*
27-05	19:00	20:00	**Invited Talk**	**I1: Invited Lecture: Manim in Physics Teaching**	**Uwe Zimmermann [Uppsala University]**		
27-05	20:00	22:00	Social Event	Networking Reception	*Bolek Pub & Restaurant*		
28-05	**Thursday**			Registration Desk and Morning Coffee starting at 8.15		*Rektorska 4 Street*	
28-05	09:00	09:15	Opening Session	Conference Opening	**AULA 1.01**		
28-05	09:15	10:00	**Plenary Lecture**	**PL1: Opening Plenary Lecture: AI in STEM education: when it works, when it doesn't, and why the difference almost always comes down to instructional design**	**Katarzyna Potęga vel. Żabik [Copernicus Science Centre, Warsaw]**		
28-05	10:00	10:20	Oral Presentation	O17: Building interactive physics simulations without writing code: the promise and the perils of AI-assisted "vibe coding"	Dariusz Aksamit		
				PATH A (AI): room 4.01 [4th floor]		**PATH B (TECH ED): room 4.04 [4th floor]**	
28-05	10:40	11:00	Oral Presentation	O1: Students' and teachers' perspectives on graded pre-class assignments in the age of artificial intelligence	Arjan Lock, Ruth Buning, Johan Van Der Tol	O6: Effectiveness of whiteboards as a collaboration tool in university physics teaching: investigations based on the ICAP framework	Silke Stanzel, Christine Lux, Claudia Schäfle
28-05	11:00	11:20	Oral Presentation	O2: Continuous examination in the age of AI: comparing "explainer videos" and two-stage exams	David Marsh	O7: What is physics? – Socratic roots and experiential learning	Hendrik Snijder
28-05	11:20	11:40	Oral Presentation	O4: AI-supported pre-class preparation to enhance inquiry-based physics learning in engineering education	Debjani Goswami	O9: Evaluation of active learning materials for engineering students in fluid dynamics: progress and difficulties addressing misconceptions	Max Uzulis, Christian Kautz
28-05	11:40	12:00	Oral Presentation	O5: AI-supported mechanistic reasoning in physics education: investigating students' explanations of core electrostatic concepts in a neuron axon – RC circuit mode	Aslihan Muazzez Ünsal, Fatma Caner	O10: Guided inquiry-based physics labs for future engineers	Yuki Kaneko
28-05	12:00	12:45	Lunch Break	Lunch Break		*Rektorska 4 Street - lobby*	
28-05	12:45	14:00	Poster Session	**Poster Session (both paths): lobby [ground floor]**			
28-05	14:00	15:30	Workshop	W1: Manim in Physics Teaching 1 [4.08]	Uwe Zimmermann	W2: Designing effective learning processes in physics with the ICAP-model for active learning [4.01]	Claudia Schäfle, Silke Stanzel
28-05	15:30	16:00	Coffee Break	Coffee Break			
28-05	16:00	17:30	Workshop	W3: Creating a student-centered collaborative learning environment in a university physics classroom [4.01]	Gerald Feldman	W4: Sensors, micro-Controllers: How do they connect [4.08]	Derek Land, Thomas Triemstra
28-05	19:00	21:00	Social Event	Conference dinner	*Stary Dom - Polish Restaurant*	*Puławska 104/ 106 Street*	*https://restauracjastarydom.pl/*
29-05	**Friday**			Registration Desk and Morning Coffee starting at 8.30		*Rektorska 4 Street*	
29-05	09:00	09:40	**Invited Talk**	**I2: Invited Lecture: From Engineering Physics to Student Innovation: Large-Scale Project-Based Learning at Polytech Nantes [4.07]**	**Thomas Lepetit [University of Nantes]**		
				PATH A [4.07]		**PATH B [4.05]**	
29-05	09:40	10:00	Oral Presentation	O12: The realization and opportunities of an educational cleanroom for engineering trainings and high-tech projects in close collaboration with the semiconductor ecosystem	Jeroen B. Oostinga	O14: Critical making in STEM teacher education: conceptual foundations and insights from professional development	Sara Durski, Holger Weitzel, Wolfgang Müller
29-05	10:00	10:20	Oral Presentation	O13: International Particle Physics Masterclasses	Małgorzata Janik, Łukasz Graczykowski	O15: Quantum Edukit: An experimental toolkit to learn quantum mechnics	Nishant Dogra
29-05	10:20	10:40				O16: Video analysis and dynamic modeling of rotation motion using tracker	Jozef Kúdelčík, Peter Hockicko, Mária Kúdelčíková
29-05	10:50	12:25	Workshop	W5: Manim in Physics Teaching 2 [4.08]	Uwe Zimmermann	W6: Using research-based instructional materials to foster conceptual understanding: tutorials in introductory physics [4.07]	Christian Kautz, Max Uzulis and Silke Stanzel
29-05	12:30	13:30	Lunch Break	Lunch Break		*Rektorska 4 Street - lobby*	
29-05	13:30	15:00	Workshop	W7: Hands-on critical making: addressing disinformation through STEM makerspaces [4.07]	Sara Durski, Holger Weitzel, Wolfgang Müller, Katarzyna Rutkowska, Miroslaw Brzozowy, Flavio Renga, Laura Farinetti	Networking / Visiting WUT	
29-05	15:00	15:30	Meeting	SIG Physics Meeting [4.08]		Networking / Visiting WUT	
29-05	15:30	16:00	Closing Session	Summary and Conference Closing [4.04]			

4.02

facilities, participants' own work, networking

4.04

facilities, participants' own work, networking

Date	Start Time	End Time	Session Type
28-05	12:45	14:00	Poster Session

No.	Poster Title	Presenter/Authors
P1	Applications of a spatial light modulator in the undergraduate optics laboratory	Agnieszka Popiołek-Masajada, Mateusz Szatkowski
P2	AI-supported problem solving as a catalyst for innovation in physics education	Peter Hockicko
P3	Designing an asynchronous introductory physics course: interaction, labs, and academic integrity in online education	Belter Ordaz, Diego Valente
P4		
P5	Flexible learning and assessment in engineering physics	Roope Siikanen, Sami Suhonen
P6	Grasping measurement uncertainty: evaluating a project-based introductory physics lab for medical physics student	Andreas Modler
P7	How Excel can help you solve physics problems	Paweł Perkowski
P8	Hybrid scaleup rooms: turning online participants into active in-person participants	Michael Wendlandt
P9		
P10	Integration of AI-tools into a physics laboratory course	Christian Hettich, Wolfgang Bührer, Bernd Jödicke
P11	Development of virtual reality radiation lab to strengthen radiation safety awareness in undergraduate students	Aleksandra K. Biegun, Pjotr Svetachov, Gert-Jan Verheij
P12	The development of an educational measurement system to perform novel electronic experiments on electrostatically gated graphene microdevices	Jeroen B. Oostinga, Johan Van Der Tol, Chris Windmeijer, Robin Weikamp, Jeathon Cooman, Hao Ru Wu, Arjan Lock
P13	A research-oriented physics workshop as an alternative to metrology and introductory physics laboratories	Katarzyna Rutkowska, Izabela Ducin
P14	AI in STEAM education: developing critical understanding and AI literacy among learners	Mirosław Brzozowy, Martyna Jakubowska, Marek Braun, Wojciech Cebula, Monika Cynar, Efstratia Liakopoulou, Eleni Paloumpa, Laura Cesaro, Emanuele Menegatti, Chrissa Papasarantou, Dimitris Alimisis, Georgia Lascaris

AI IN STEM EDUCATION: WHEN IT WORKS, WHEN IT DOESN'T, AND WHY THE DIFFERENCE ALMOST ALWAYS COMES DOWN TO INSTRUCTIONAL DESIGN

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Technologies such as AI typically enter education systems on two grounds: schools are expected to prepare young people for lives and work shaped by these tools, and new technologies are repeatedly introduced with the promise of improving or optimising teaching and learning. Yet every technology that enables cognitive offloading reopens a fundamental educational question: what should count as knowledge and understanding, what may be delegated to tools, and what must remain part of human learning. Cognitive offloading - the reduction of mental effort through reliance on external supports - is not a new phenomenon; writing, maps, and clocks are among its oldest examples. The question, then, is not only what such tools make easier, but also what may be lost when cognitive work is systematically delegated to them.

Alongside these broader concerns, educators and policymakers face a more practical set of questions: how should such tools be introduced, under what conditions, and with what safeguards? To address these issues, I revisit historical cases of educational technology adoption, drawing on the structural pattern identified by Larry Cuban [1, 2]: initial promise and high expectations, followed by investment and equipment purchases, classroom adaptation or quiet resistance, and ultimately, disappointment or calls for a reset.

In the final section, I present a model for designing and implementing educational innovation grounded in ten years of experience at the Copernicus Science Centre. The model is structured as an iterative process that integrates research, design, and classroom practice: teachers are positioned as co-researchers, students engaged as active participants in testing and refinement, and institutional constraints treated not as barriers but as core design conditions.

[1] L. Cuban (1986). Teachers and Machines: The Classroom Use of Technology Since 1920. Teachers College Press.
[2] L. Cuban (2001). Oversold and underused: computers in the classroom. Cambridge: Harvard University Press. https://doi.org/10.4159/9780674030107

MANIM IN PHYSICS TEACHING

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MANIM, from Mathematics and Animations, is a Python library which was created by the well-known Youtube profile Grant Sanderson, aka 3Blue1Brown. Grant has a background as educator in the established Khan Academy. His introductory videos to basic and advanced mathematical and scientific videos cover a wide range from algebra to quantum computing. In order to present the concepts in his videos he created a library of helper functions which spread to other educators during the time of increased online teaching in the corona pandemic. Since the library was primarily programmed by Grant for his own use, he deemed it to be almost unusable by everyone else before a group of enthusiasts formed and started to develop a "community edition" branch, eradicating many bugs and writing a comprehensive documentation including examples for many simpler use cases. During the time 2020 to 2023 even external plugins were added for specific areas like physics and chemistry - even though these have not seen the same intense development as the core of the library. I myself came first into contact with the library just before corona, but gave up on it, because of the lack of documentation. Instead I developed some basic animations for my electronics courses using LaTeX. In late 2021 I revisited the project and since then I have used the ManimCE library for many animations from analog and digital electronic circuits and mathematical derivations of complex impedances and linear regression methods to band diagrams in semiconductor devices. In my spare time I have become active in the online ManimCE community as well, where I help new and advanced users to find programmatic solution to their animation ideas.

In this talk I will present some of the animations I have made over the years as complementary teaching material for my students, predominantly in engineering physics. I will discuss my pedagogical ideas and concepts and where I believe these animations find their place. I will also present some concepts utilized by other users of Manim and pose the question which kinds of animations might be more or less useful in conveying the concepts we intend to teach and how to possibly get the most gain from a tool like Manim.

FROM ENGINEERING PHYSICS TO STUDENT INNOVATION: LARGE-SCALE PROJECT-BASED LEARNING AT POLYTECH NANTES

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How can physics remain rigorous, useful and motivating for engineering students? This talk will present a large-scale interdisciplinary project-based learning module developed at Polytech Nantes in the second year of the integrated preparatory cycle. Each year, approximately 144 students work in 12 large teams on projects connecting physics, engineering practice, digital tools and societal or industrial issues. This team size is a deliberate compromise: it creates authentic project-management constraints while keeping supervision manageable.

The module is organized into three phases: training, production and presentation. Initial training sessions help students become progressively autonomous through project management, bibliographic research, scientific writing and digital tools. The production phase is central: students are expected to deliver a concrete outcome, such as a prototype, numerical simulation, IoT system, application or data analysis tool. This tangible objective strongly supports motivation and helps connect physics concepts to engineering practice.

Assessment combines collective deliverables and individual evaluation. Teams submit a preliminary project proposal, intermediate milestones and a final report, and present their work in a final conference. Each student also submits an individual contribution sheet and takes part in a short interview, allowing both personal involvement and understanding of the whole project to be assessed. This limits task fragmentation within large teams and encourages fair engagement.

The talk will highlight the organizational conditions needed for such a format: dedicated support from technical staff, involvement of academic experts and researchers, and participation of industrial and socio-economic partners in the final jury. Concrete student achievements will also be presented. Last year, two projects were communicated at the French national photovoltaic conference: an instrumented high-altitude balloon for qualifying commercial CIGS photovoltaic modules, and a neural-network-assisted extraction of single-diode model parameters from photovoltaic I–V curves.

Finally, the presentation will discuss lessons learned and current challenges, including the role of AI tools, which can support autonomy but also require careful assessment to ensure genuine scientific understanding.

STUDENTS' AND TEACHERS' PERSPECTIVES ON GRADED PRE-CLASS ASSIGNMENTS IN THE AGE OF ARTIFICIAL INTELLIGENCE

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The Applied Physics bachelor's programme at The Hague University of Applied Sciences is increasingly using a flipped classroom approach for its theoretical courses. For successful implementation of this model, students prepare for class by completing pre-assigned activities to familiarize themselves with the course subject. This is typically done by watching videos, reading texts or taking quizzes. Classroom time can be used to do either collaborative exercises, have discussions or in-depth lectures. In this way the interaction with the lecturer is maximized [1].

A few years ago, we began assigning short textbook readings as pre-class work for our students. To encourage the student to do this pre-class work, we introduced a bonus grade system: students could earn up to a 1.0-point bonus. This bonus is added to their exam work (graded from 1.0 to 10.0, with 10.0 the maximum score). The bonus was awarded for answering a set of simple multiple-choice questions and calculations based on the textbook reading. The final question was open-ended, asking students to identify any difficulties they encountered in the textbook. This feedback allowed teachers to optimize their lectures by addressing the most mentioned difficulties.

With the rise and widespread use of AI, we observed that a substantial part of our students achieved higher scores for these pre-class homework questions while spending less time on them. As a result, the system lost its effectiveness as learning tool for part of the students and real preparation did not take place. To address this drop in effectiveness, we modified our approach for motivating students to complete pre-class work.

To help students stay on track, we implemented several different bonus grade systems across different courses. Among these approaches were voluntary small weekly bonus quizzes after each lecture, short 20-minute multiple choice tests every three weeks and in-lecture grading using interactive tools like wooclap [2]. Each bonus method was used in a specific course, either 2nd or 4th year, with varying numbers of participants. The courses involved are among others: Optics, Laser Physics, Spectroscopy, Medical Imaging and Research II. We will present the observed outcomes of these methods, combining insights from teacher observations as well as feedback from students from surveys and discussions.

[1] G. Akçayır, M. Akçayır (2018). The flipped classroom: A review of its advantages and challenges. Computers and Education, 126, 334–345.
https://doi.org/10.1016/j.compedu.2018.07.021
[2] https://www.wooclap.com

CONTINUOUS EXAMINATION IN THE AGE OF AI: COMPARING "EXPLAINER VIDEOS" AND TWO-STAGE EXAMS

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Take-home assignments play a central role in many physics and engineering courses. Well-constructed assignments give students the opportunity to hone their problem-solving skills and may help them develop higher-order skills, e.g., by synthesising or analysing the material. Moreover, take-home assignments serve as an example of continuous assessment, encouraging deep study throughout the course and providing opportunities to demonstrate skills before the final examination. For these reasons, many instructors cherish take-home assignments as a pedagogical instrument.

However, the rapidly expanding problem-solving capabilities of readily available AI tools risk making take-home assignments less effective as pedagogical instruments and raise issues of authenticity. Moreover, while traditional take-home assignments can expose students to the appropriate level of challenge, individual feedback is often delayed by a time-consuming grading process, thereby reducing the assignments' pedagogical effectiveness.

In this project, we have explored alternative forms of continuous assessment through an intervention conducted in a second-year *Electromagnetism & Waves* course in the Physics program at Stockholm University in the Spring term of 2026. The goal is to evaluate and compare two forms of continuous assessment that may be less severely affected by AI tools, and in which peer interactions provide timely feedback.

The continuous assessment in this course was based on six problem sets. The first three of these were assessed through "*Explainer Videos*" with peer review; the last three were assessed through short, in-class *"Two-Stage Exams"*. Explainer Videos are self-recorded videos where the students explain their solution to an assigned problem, guided by a grading rubric. The submitted videos are subsequently peer reviewed within a week of submission. Explainer Videos have been used at Stockholm University since 2020, and in this particular course since 2025. In Two-Stage Exams, students first take an individual test, which is immediately followed by a collaborative, second test, typically with the same or very similar questions [1, 2]. Two-stage exams have been successfully used for mid-term exams and final exams [3, 4]. Here, we explore how a shortened, focused version can be used for weekly continuous assessment.

We present results of this intervention based on student survey data, teaching assistant interviews, and self-reflections. We compare the two formats along several dimensions, including perceived learning value, robustness to AI-generated solutions, feasibility of implementation, and self-efficacy [5]. We argue that both formats offer complementary advantages for continuous assessment in the age of generative AI, and we identify conditions under which each is most effective.

[1] P. Heller, R. Keith, and S. Anderson (1992). Teaching problem solving through cooperative grouping. Part 1: Group versus individual problem solving. Am. J. Phys. 60, 627–636
[2] P. Heller, M. Hollabaugh (1992). Teaching problem solving through cooperative grouping. Part 2: Designing problems and structuring groups. Am. J. Phys. 60, 637–644.

[3] C. Wieman, G.W. Reiger, and C.E. Heiner (2014). Physics exams that promote collaborative learning. Phys.Teacher, 52, 51–53.
[4] K. Callaghan, T. Milbourne, A. Klales, G. Kestin, C. Arguelles, L. McCarty, L. Deslauriers. Two-Stage Final Exams: An Assessment Strategy for Enhanced Collaborative Learning and Reduced Student Stress. preprint arXiv:2504.04281 [physics.ed-ph].
[5] A. Bandura (1977). Self-efficacy: Toward a unifying theory of behavioral change. Psych. Rev., 84(2), 191–215.

AI-SUPPORTED PRE-CLASS PREPARATION TO ENHANCE INQUIRY-BASED PHYSICS LEARNING IN ENGINEERING EDUCATION

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Artificial intelligence (AI) is increasingly used to support learning, feedback, and student engagement in higher education, particularly in STEM disciplines [1]. In physics education for engineering and foundation-level students, integrating digital learning tools with inquiry-based laboratory activities can strengthen conceptual understanding and improve preparedness for active classroom learning [2].

This work explores how AI-supported preparatory activities can improve student readiness for inquiry-driven laboratory learning in foundation-level physics courses while maintaining the central role of traditional hands-on experimentation.

The teaching approach integrates several AI-assisted components to support pre-class preparation. AI-generated HTML simulations allow students to explore conceptual physics scenarios before attending the class. For example, in a circular motion topic, students interact with a virtual model of a rotating shaft lifting a weight, enabling them to observe relationships between rotational motion, force, and mechanical work prior to performing the physical experiment. Similar AI-supported simulations are also used to help students analyse complex electrical circuit problems by visualising current flow and voltage relationships. In addition, AI-generated numerical questions and guided solutions provide opportunities to practise problem-solving before class. Short "topic-at-a-glance" summaries support quick conceptual review, while AI-assisted assessment tools enable rapid formative feedback.

Preliminary observations indicate that students using AI-supported preparatory materials show improved readiness for laboratory experiments and greater participation in conceptual discussions. Student feedback also highlights that regular homework resources and weekly practical sessions support understanding and engagement. AI-supported learning environments can further enhance student engagement and problem-solving skills in STEM education [3].

The approach demonstrates how AI tools can complement rather than replace traditional inquiry-based teaching practices. By supporting preparation before class, AI allows classroom time to focus on guided questioning, conceptual dialogue, and experimental investigation. The proposed model therefore offers a transferable framework for integrating AI-supported preparation within physics teaching for engineering and foundation-level STEM education [4].

[1] O. Zawacki-Richter, V. I. Marín, M. Bond, F. Gouverneur (2022). Systematic review of research on artificial intelligence applications in higher education. International Journal of Educational Technology in Higher Education 19, 1–27.
https://doi.org/10.1186/s41239-019-0171-0

[2] M. Bond, H. Khosravi, M. De Laat, N. Bergdahl, V. Negrea, E. Oxley, P. Pham, S. W. Chong, G Siemens (2024). A meta systematic review of artificial intelligence in higher education: A call for increased ethics, collaboration, and rigour. International Journal of Educational Technology in Higher Education, 21(1), 4. https://doi.org/10.1186/s41239-023-00436-z

[3] E. Kasneci, et al. (2023). ChatGPT for good? On opportunities and challenges of large language models for education. Learning and Individual Differences 103, 102274.
https://doi.org/10.1016/j.lindif.2023.102274

[4] H. Crompton, D. Burke (2023). Artificial intelligence in higher education: The state of the field. Computers and Education: Artificial Intelligence 4, 100119.
https://doi.org/10.1186/s41239-023-00392-8

AI-SUPPORTED MECHANISTIC REASONING IN PHYSICS EDUCATION: INVESTIGATING STUDENTS' EXPLANATIONS OF CORE ELECTROSTATIC CONCEPTS IN A NEURON AXON – RC CIRCUIT MODEL

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Understanding scientific phenomena in physics requires more than applying formulas; it requires explaining the causal mechanisms underlying physical processes. In science education literature, such explanations are described as mechanistic reasoning. Mechanistic reasoning involves identifying the entities and their properties within a system, and the interactions among them that collectively produce observable outcomes [1]. Rather than relying solely on mathematical relationships, mechanistic explanations articulate the causal processes that link physical concepts. With the rapid development of generative artificial intelligence (AI) tools, new learning environments have emerged that may support students' reasoning processes. However, it remains unclear whether interactions with AI systems foster deeper mechanistic reasoning or simply encourage answer-seeking behaviors. Investigating how students construct mechanistic explanations while interacting with AI therefore, represents an important research problem in physics education. The purpose of this study is to examine the mechanistic explanations of first-year undergraduate students in AI-supported learning environments and to contribute to the physics education literature by analyzing how freshmen construct causal explanations of physical phenomena. The study is situated within the interdisciplinary freshmen science course at Sabancı University. This course aims to equip students with basic Physics, Biology, and Chemistry concepts. The study focuses on students' reasoning about core electrostatics concepts such as; electric field, potential and energy associated with the field, and work, in the context of modeling the neuron axon with simple electric circuits. By analyzing students' written explanations, AI interaction logs, and interview data, the study aims to reveal how students develop causal explanations of physical processes and how AI interactions influence these reasoning patterns. The study employs an explanatory sequential mixedmethods. Participants are undergraduate students enrolled in the above mentioned science course. Data is collected at multiple stages of the instructional sequence, including before and after lectures. In the final stage, students participate in an AI-supported reasoning session designed to encourage mechanistic explanations. Students' explanations are analyzed using a mechanistic reasoning coding framework adapted from Russ et al. (2008), which identifies key mechanistic elements such as entities (e.g., ions and electric field), interactions (electric force), and outcomes (changes in electric potential across the membrane).

[1] R. S. Russ, R. E. Scherr, D. Hammer, J. Mikeska (2008). Recognizing mechanistic reasoning in student scientific inquiry: A framework for discourse analysis developed from philosophy of science. Science education, 92(3), 499-525.

EFFECTIVENESS OF WHITEBOARDS AS A COLLABORATION TOOL IN UNIVERSITY PHYSICS TEACHING: INVESTIGATIONS BASED ON THE ICAP FRAMEWORK

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The widespread use of generative AI makes active and collaborative learning in class all the more important for acquiring a deep understanding of physical concepts. Analog whiteboards are a central element of the teaching methods used in physics education research. In physics courses at the Technical University of Applied Sciences in Rosenheim, students work on tasks in groups of two or three using DIN A2-sized whiteboards. These serve as a "public thinking space" that facilitates the recording and revision of ideas, promotes collaboration, and enables the teacher to quickly assess the work and provide feedback.

The study examines whether and how whiteboards support constructive and interactive learning in line with the ICAP framework [1]. Through classroom observations, the activities of the students and the teacher are recorded at two-minute intervals and assigned to the ICAP modes. In addition, the extent to which the teacher can contribute to reaching the interactive mode is analyzed.

The results show that the usage of whiteboards with groups of two to three people, and round tables in the SCALE-UP room creates favorable conditions for constructive and interactive learning processes. Students worked constructively (C) and interactively (I) at the high ICAP modes for around 80% of the time. There are also indications that whiteboard tasks of at least ten minutes duration increase the likelihood of students reaching the higher ICAP modes.

[1] M.T.H. Chi, R. Wylie (2014). The ICAP Framework: Linking Cognitive Engagement to Active Learning Outcomes. Educational Psychologist, 49(4), 219-243. https://doi.org/10.1080/00461520.2014.965823

WHAT IS PHYSICS? – SOCRATIC ROOTS AND EXPERIENTIAL LEARNING

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A minds-on oral presentation about a new course at The Hague University of Applied Sciences in which an ongoing Socratic dialogue is used to construct a collective vision of applied physics among first-year bachelor students. In its novel approach, students develop professional capabilities through the integration of transferable skills, which will be used in later stages of the study program and in the professional field.

Students broaden their knowledge of physics during guest lectures, experiments and workshops taught by external physicists and engineers. Real-life gatherings foster calibration of ideas while ethical questions and broader perspectives on society emerge. In the meantime students develop their own opinions by reading, visiting professionals and taking structured notes in a digital journal. Future versions of the course welcome contributions from international institutions.

By the end of the semester students have developed critical thinking, technical report writing, presentation skills, and reflection techniques. They have learned to articulate their thoughts both orally and in writing. The learning goals where focused on self-reflection and report writing. At the end of the course, students use their journal to answer one final question, “What is Physics?”.

In an evaluation of the course, almost all students identified the broad perspective on physics and the future professional field as the most valuable and novel aspect. This is also reflected in their final essay’s on ‘What is Physics?’, in which they explained there new insights into the field using the reflection techniques. Suggested improvement are of a practical nature.

EVALUATION OF ACTIVE LEARNING MATERIALS FOR ENGINEERING STUDENTS IN FLUID DYNAMICS: PROGRESS AND DIFFICULTIES ADDRESSING MISCONCEPTIONS

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Students in engineering sciences engage intensively with physics content in several foundational courses. Fluid dynamics in particular is a complex subject that requires strong groundwork in mechanics and mathematics. It also presents significant challenges for students. To address these challenges, we have been investigating students' specific conceptual difficulties in fluid mechanics since 2023. Using regular short quizzes during the semester as well as broad conceptual diagnostic tests at the start and end of each semester we could observe misconceptions and faulty reasoning patterns.

Based on the results, activating learning materials were developed to enhance the traditional teaching format in 2024 and 2025. In this new format, the traditional lecture was kept as is but the small-group sessions were changed. Usually students discuss calculation-heavy homework with tutors in these sessions without going into the why and how of the calculations. In the new format, between 5 and 8 out of 13 sessions were replaced with active learning materials where students work in groups of four to reason and think together about the fundamental concepts of fluid mechanic.

In this study, we present quantitative and qualitative data on the effectiveness of the intervention. Pre- and post-test questions on three core concepts of fluid dynamics (hydrostatic pressure, the continuity principle, and the Bernoulli equation) were analyzed in order to draw conclusions about students' misconceptions and how to better address them. On the one hand, the results demonstrate successes in terms of reducing misconceptions and improving test scores in hydrodynamics. Post-intervention items in hydrostatic showed a 29% increase in correct answers compared to the no-intervention population while average scores on the pre-intervention items were practically the same for both cohorts. Also, students who attended the intervention session on hydrostatics showed 15% to 25% reduced likelihood to demonstrate specific misconceptions in hydrostatics compared to students in the same year that did not attend the intervention. On the other hand, we report on certain difficulties that proved to be persistent. Students confronted with a specific scenario (narrowed pipe) in which the continuity principle needs to be applied correctly to yield the correct answer during the intervention, still showed comparable misconceptions (and incorrect answer scores) in the post-intervention quiz item when confronted with a slightly different scenario (height difference in pipe). These findings imply a complex, granular and subject specific view of misconceptions in fluid mechanics that prompted further revisions to the teaching materials for the summer semester of 2026.

GUIDED INQUIRY-BASED PHYSICS LABS FOR FUTURE ENGINEERS

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Traditional introductory physics labs, in which students follow step-by-step experimental procedures, fill out the data tables provided and follow the analysis procedures, often fail to engage them in high order scientific thinking while performing experiments [1]. These labs are intended to enhance the conceptual understanding level of physics topics, yet the effectiveness of such labs is unclear [2]. What then, is the role of labs in an introductory physics course for engineering students? How can labs engage them in deeper thinking and discussions for better learning?

In our uniquely-designed basic physics course for engineering students, we implemented a lab component in Fall 2025. When designing the labs, we employed a guided inquiry-based approach, in which students are provided scaffolding in designing their own investigations. The inquiry-based approach not only allows students to observe the actual physical phenomena but also challenge students to wonder and think, and help equip them with the skills for scientific investigations. We find that the "guided" aspects are necessary for our students, most of whom are novice to real scientific investigations. The students kept lab logbook during each lab, reflecting real scientific laboratory practices.

In this talk, I will share the overall design and a few examples of our labs, including prelab worksheets, lab instructions with engineering application scenarios, and individual "think and explain" questions. The preliminary results of post-semester lab survey show that the students gained confidence in their ability to design, conduct, and analyze physics experiments, while also benefiting from the labs in terms of learning the concepts. The current status and remaining challenges will also be discussed.

[1] M.S. Smith, M.M. Stein, C. Walsh, N.G. Holmes (2020). Direct Measurement of the Impact of Teaching Experimentation in Physics Labs. Phys. Rev. X 10, 011029. https://doi.org/10.1103/PhysRevX.10.011029
[2] C. Wieman, N.G. Holmes (2015). Measuring the impact of an instructional laboratory on the learning of introductory physics. American Journal of Physics, 83, 972–978. https://doi.org/10.1119/1.4931717

THE REALISATION AND OPPORTUNITIES OF AN EDUCATIONAL CLEANROOM FOR ENGINEERING TRAININGS AND HIGH-TECH PROJECTS IN CLOSE COLLABORATION WITH THE SEMICONDUCTOR ECOSYSTEM

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Europe has started to initiate, expand and strengthen Chip Competence Centers in several countries since the European Chip Act announcement in 2022 [1]. The Netherlands has initiated in 2024 the program "Operation Beethoven" to build-up training centers with the mission to educate and train technical students at different educational levels for the semiconductor industry [2].

Currently, a professional ISO-7 cleanroom is realized at The Hague University of Applied Sciences in Delft in collaboration with vocational schools, academic universities and other universities of applied sciences in the South-Holland region. The new 100 m^2 cleanroom consists of two sectors: (1) a 'microfabrication sector' for lithography process flows and micron-scale metrology, and (2) an 'assembly & testing sector' for working on macroscopic high-precision semiconductor equipment and related subsystems. Additionally, a classroom is realized dedicated to theory modules as well as courses on design, modelling and simulation software which are relevant for the microchip ecosystem.

In this presentation, I will explain how this cleanroom enables interdisciplinary education, training opportunities to develop hands-on skillsets, and cross-functional collaborations within the microchip ecosystem. I will elaborate on examples of cleanroom activities for students at different competence levels [3], from basic cleanroom trainings to innovative applied research projects (e.g., in collaboration with internal research groups, external research institutes, startups/scale-ups and SMEs). The new cleanroom will provide students unique opportunities to get-to-know the microchip ecosystem, and to connect to semicon professionals at companies who can support -and possibly guide- young professionals to start a career in the semiconductor industry.

[1] European Commission. A chips act for Europe. https://www.european-chips-act.com/COM_2022_45_1_EN.pdf
[2] Gerichte groei voor semicon-talent in de regio Delft – Nationaal Versterkingsplan Microchiptalent Regioplan Zuid-Holland Delft. https://www.dehaagsehogeschool.nl/media/beethoven-regioplan-zuid-holland-delft-30-september-2024
[3] Jeroen B. Oostinga. Lithography challenges for physics and engineering students to become competent, skillful microtechnologists for the semiconductor industry. Proceedings of the PTEE 2024. https://opus4.kobv.de/opus4-rosenheim/files/2581/PTEE2024_Oostinga_LITHOGRAPHY_CHALLENGES_FOR_.pdf

INTERNATIONAL PARTICLE PHYSICS MASTERCLASSES

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An educational activity, the International Particle Physics Masterclasses [1], was developed by the International Particle Physics Outreach Group [2] with the aim to bring the excitement of cutting-edge particle-physics research into the classroom. Since 2005 they have been hosted in research centers or universities close to their schools. Each year 13 000 students from 60 countries become 'scientists for a day' as they are introduced to the mysteries of particle physics. The program of a typical day includes lectures that give insight into topics and methods of fundamental research followed by a 'hands-on' session where the high-school students perform themselves measurements on real data from particle-physics experiments. The day concludes with a videoconference, during which students will connect with scientists from CERN as well as other institutions that will be carrying out the same exercise on that day. During the videoconference, students present the results of their analyses and have the opportunity to speak with scientists as well as with their peers from other countries.

In this talk, we will present the Masterclass concept and the methodology employed in its implementation. We will also share our experience from more than ten years of organizing Masterclass events at WUT based on data of ALICE/LHC experiment at CERN. This includes perspectives gained as a local event organizer, a tutor supporting other institutes, a coordinator involved in the development of the analysis application used by students, and a remote expert participating in videoconferences. It should be emphasized that the application [3] used for the ALICE measurements was developed and is maintained entirely at WUT. The presentation will highlight both practical aspects of running such activities and insights into their educational impact.

[1] Masterclass Webpage.
https://ippog.org/imc-international-masterclasses
[2] IPPOG Webpage.
https://ippog.org/
[3] ALICE Masterclass Webpage.
https://alice-web-masterclass.app.cern.ch/

CRITICAL MAKING IN STEM TEACHER EDUCATION: CONCEPTUAL FOUNDATIONS AND INSIGHTS FROM PROFESSIONAL DEVELOPMENT

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The spread of misinformation and manipulated digital content highlights the need to strengthen critical thinking in education. Policy initiatives and empirical work emphasize that improving media literacy and critical analysis skills is essential for building societal resilience against disinformation and enabling decision-making [1,2]. At the same time, maker education has gained attention as an experiential approach fostering creativity, collaboration, and problem-solving. Critical Making [3] provides a pedagogical bridge between these perspectives by linking hands-on technological design with structured critical reflection on socio-technical systems. The concept connects material engagement with technologies to critical reflection on the societal implications of innovations. Despite this growing interest, the conceptual foundations and implications of Critical Making for teacher education remain insufficiently defined.

Our study addresses two questions: (1) How can Critical Making be conceptualized for STEM teacher education? (2) What insights emerge from the formative evaluation of teacher professional development implementing this approach? To address these questions, a two-round Delphi study with European experts from education and STEM fields was conducted, combining semi-structured interviews and a structured questionnaire. In addition, formative evaluation data from an iterative teacher program on Critical Making were analyzed using survey data and qualitative feedback.

Experts show strong agreement on key principles of Critical Making: iterative design processes, self-determined learning, and structured reflection linking making activities to societal and technological implications. The findings suggest that Critical Making extends maker education by embedding critical inquiry within design processes. Evaluation results indicate that teachers perceive the approach as promising, while challenges remain regarding curricular integration and assessment.

At the conference, we would like to discuss initial insights for conceptualizing Critical Making in teacher education and the need for further research.

[1] European Commission: Directorate-General for Education, Youth, Sport and Culture, Guidelines for teachers and educators on tackling disinformation and promoting digital literacy through education and training, Publications Office of the European Union, 2026. https://data.europa.eu/doi/10.2766/5220136

[2] G. Huang, W. Jia, & W. Yu (2024). Media Literacy Interventions Improve Resilience to Misinformation: A Meta-Analytic Investigation of Overall Effect and Moderating Factors. Communication Research, 0(0). https://doi.org/10.1177/00936502241288103

[3] R. Sipos, & M. Åkerman (2023). Introducing the Critical Making Responsibility framework for analyzing responsible innovation processes in grassroots practices. Innovation: The European Journal of Social Science Research, 36(4), 652–672. https://doi.org/10.1080/13511610.2023.2195583

QUANTUM EDUKIT:
AN EXPERIMENTAL TOOLKIT TO LEARN QUANTUM MECHANICS

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With the advancements in quantum technologies, it is essential that the basic understanding of quantum mechanics reaches students, the general public and policy makers in an intuitive way.

We have developed Quantum Edukit (weblink), an educational kit based on NitrogenVacancy (NV) centers to teach quantum mechanics in a hands-on and interactive manner. The kit enables exploration of principles such as level quantization, quantum superposition, lightmatter interaction and quantum optical effects in real time. Sample experiments include observation of the Zeeman effect, Rabi oscillations, Ramsey interferometry, and spin echo. Moreover, Quantum Edukit demonstrates how these principles underpin real-world applications including quantum magnetometry, atomic clocks, and qubit manipulation. On an experimental level, students gain hands-on experience in building optical setups, optimizing the performance of quantum systems, and acquiring hand-on skills used in quantum research labs.

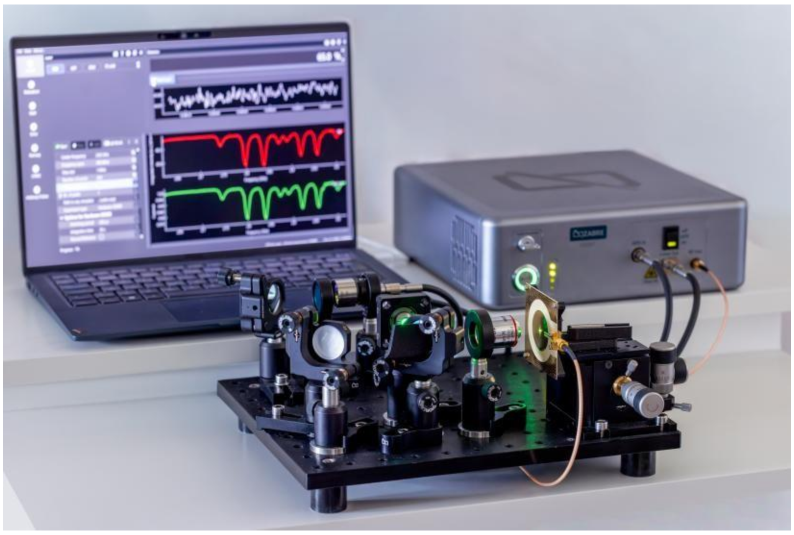

Figure 1: Quantum Edukit

The kit comprises an optical setup, an electronics setup, and custom software, see Figure 1. Optimized for portability and live data visualization, it is ideal for lecture demonstrations and gives students an opportunity to play with the system and observe its real-time response.

By making quantum systems more accessible through a compact and versatile platform, Quantum Edukit aims to deepen students’ understanding of quantum mechanics and enhance their engagement with quantum technologies.

VIDEO ANALYSIS OF THE ROTATIONAL MOTION OF A CYLINDER USING TRACKER

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Contribution is focused on the rotational motion of a cylinder, which represents one of the simplest types of rotational motion. Using video analysis in Tracker [1], the key characteristics of this motion, such as the rotation angle, angular velocity, and angular acceleration, are analyzed and explained [2]. Tracker is a free video analysis and modeling tool built on the Open Source Physics Java framework and is widely used in physics education. It enables students to analyze real experiments through video recordings and to extract quantitative data from them. Based on these data, students can determine the time dependence of physical quantities describing the observed motion. The software can be effectively used both by students in physics seminars and by instructors during lectures to illustrate key concepts and demonstrate the relationships between physical quantities.

Rotational motion is typically introduced in the first year of university physics courses, at a stage when students have already mastered the kinematics of motion in one and two dimensions. Through the video analysis of the uniform rotational motion of a cylinder, the relationships between the physical quantities describing this motion in both polar and Cartesian coordinate systems are clearly demonstrated. However, rotational motion is usually presented only as rotation about a fixed, immobile axis. With the aid of video analysis, it is possible to extend this understanding to the uniform rolling motion of a cylinder on a plane, which combines the translational motion of the center of mass with its rotational motion about that point. The analysis of the center of mass motion employs a uniformly moving coordinate system associated with this point. The final part of the analysis is focused on a cylinder rolling down an inclined plane, where it is necessary to apply previously acquired knowledge of accelerated motion. The rotational motion of a cylinder is further analyzed for different angles of inclination of the plane. For students with prior knowledge of rigid body dynamics, the relationships between kinematic quantities and rotational kinetic energy are also demonstrated, including the connection between angular velocity and the moment of inertia, as well as the role of energy conservation during rolling motion without slipping. In this context, video analysis provides an effective link between theoretical studies of motion and their real-world applications.

[1] https://opensourcephysics.github.io/tracker-website/
[2] J. Kúdelčík, P. Hockicko and M. Kúdelčíková (2022). The application of program Tracker at the analyse of rotation motion, ELEKTRO 2022, Krakow, Poland, pp. 1-4.

Acknowledgments
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BUILDING INTERACTIVE PHYSICS SIMULATIONS WITHOUT WRITING CODE: THE PROMISE AND THE PERILS OF AI-ASSISTED "VIBE CODING"

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Interactive simulations are among the most effective tools for teaching physics, yet building them has traditionally required programming skill that most physics educators do not possess. This contribution reports a practical experience of creating sophisticated, browser-based interactive physics simulations entirely through natural-language interaction with AI agents – an approach often called "vibe coding" – without the author writing any code. The work presents both the opportunity this represents for engineering and physics education and the risks that arise when AI-generated output is not rigorously supervised.

The bright side: working with conversational AI tools (ChatGPT, Gemini) and an AI application-development agent (Lovable), the author produced two publicly accessible educational simulations in the field of medical physics: an interactive computed-tomography imaging sandbox and an eleven-lesson radiotherapy treatment-planning course. Features that an educator might assume to be beyond reach were implemented with minimal effort: a functional Dose-Volume Histogram, real-time Filtered Back Projection reconstruction, and algorithmic optimization that the AI agent diagnosed and implemented, reducing a dose calculation from twenty seconds to one. The development effort was a small fraction of what conventional software development would require, placing semi-professional-grade interactive tools within reach of any educator.

The dark side: the same fluency that makes AI assistance powerful can mask substantive errors. AI-generated anatomical models contained mistakes that no expert eye was needed to catch – a heart placed on the wrong side of the chest, lungs intersecting the rib cage, and an S-shaped scoliotic spine produced in response to a request for normal curvature. None of these errors would be detected by the AI itself, and in less obvious setup a non-supervising user would publish them unknowingly. The central message for educators is that "vibe coding" does not remove the expert from the loop; it relocates the expert's role from programmer to pedagogical director and content validator – a role that becomes more, not less, important.

The presentation will demonstrate the simulations live, recount the development process candidly including its failures, and offer concrete guidance for engineering-physics educators who wish to build their own interactive tools while avoiding the pitfalls of unsupervised AI-generated content. The relevance for physics teaching in engineering education is direct: AI-assisted development lowers the barrier to creating active-learning resources, but only disciplined, expert supervision turns that capability into trustworthy teaching material.

[1] J. M. Fagerstrom, W. Gao, G. E. Robertson (2019). A hands-on introduction to medical physics and radiation therapy for middle school students. Journal of Applied Clinical Medical Physics, 20(4), 148–153.
[2] V. J. Montemayor, E. L. Bossart, J. W. Burmeister, et al. (2025). AAPM WGTEACH Report 366: Best practices in the teaching and mentoring of medical physics. Journal of Applied Clinical Medical Physics, 26, e70259.

MANIM IN PHYSICS TEACHING

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MANIM, from Mathematics and Animations, is a Python library which was created by the well-known Youtube profile Grant Sanderson, aka 3Blue1Brown. Grant has a background as educator in the established Khan Academy. His introductory videos to basic and advanced mathematical and scientific videos cover a wide range from algebra to quantum computing. In order to present the concepts in his videos he created a library of helper functions which spread to other educators during the time of increased online teaching in the corona pandemic. Since the library was primarily programmed by Grant for his own use, he deemed it to be almost unusable by everyone else before a group of enthusiasts formed and started to develop a "community edition" branch, eradicating many bugs and writing a comprehensive documentation including examples for many simpler use cases. During the time 2020 to 2023 even external plugins were added for specific areas like physics and chemistry - even though these have not seen the same intense development as the core of the library. I myself came first into contact with the library just before corona, but gave up on it, because of the lack of documentation. Instead I developed some basic animations for my electronics courses using LaTeX. In late 2021 I revisited the project and since then I have used the ManimCE library for many animations from analog and digital electronic circuits and mathematical derivations of complex impedances and linear regression methods to band diagrams in semiconductor devices. In my spare time I have become active in the online ManimCE community as well, where I help new and advanced users to find programmatic solution to their animation ideas.

In this talk I will present some of the animations I have made over the years as complementary teaching material for my students, predominantly in engineering physics. I will discuss my pedagogical ideas and concepts and where I believe these animations find their place. I will also present some concepts utilized by other users of Manim and pose the question which kinds of animations might be more or less useful in conveying the concepts we intend to teach and how to possibly get the most gain from a tool like Manim.

DESIGNING EFFECTIVE LEARNING PROCESSES IN PHYSICS WITH THE ICAP-MODEL FOR ACTIVE LEARNING

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Do you know this situation? The learning objective is clearly defined, but when it comes to designing the lesson, it is unclear with which learning activity students can achieve it most effectively. What should students actually do to achieve successful learning?

This is exactly where the ICAP model [1,2] can help. It is easy to understand and can be applied immediately and practically to the design of your teaching. This model provides a four-level taxonomy – Interactive, Constructive, Active, and Passive – that classifies student learning activities in terms of cognitive engagement. Each level is associated with a different expected depth of learning outcomes.

With this knowledge, even small adjustments to tasks and questions can guide students toward deeper learning and understanding. This is particularly valuable in physics when student should develop a deeper conceptual knowledge rather than memorizing content.

In this workshop, you will first learn how the ICAP model can be applied to the planning and designing in physics teaching practice by different learning activities. In a second step you will use the model to upgrade your own learning activities and tasks. Please bring short examples from your own class (e.g., a short lecture with a follow-up question, a problem-solving activity, a review task, an exercise, or simply specific questions you ask during your lecture).

By the end of the workshop, you will be able to design and upgrade learning activities to enhance student learning.

Learning objectives:

The participants of the workshop …

- understand and apply the ICAP model to describe active learning.
- classify different learning activities according to the ICAP model.
- develop or upgrade learning tasks that promote deeper learning.
- understand how small changes can have a significant impact on the depth of learning, particularly when shifting from active to constructive learning activities.
- plan courses with the perspective to selecting learning tasks that align with the learning objectives.

[1] M.T.H. Chi and R. Wylie (2014). The ICAP Framework: Linking Cognitive Engagement to Active Learning Outcomes. Educational Psychologist, 49(4), 219-243. https://doi.org/10.1080/00461520.2014.965823

[2] M. T. H. Chi, J. Adams, E. B. Bogusch, C. Bruchok, S. Kang, M. Lancaster, R. Levy, N. Li, K. L. McEldoon, G. S. Stump, R. Wylie, D. Xu, & D. L. Yaghmourian (2018). Translating the ICAP Theory of Cognitive Engagement Into Practice, Cognitive science, 42(6), 1777-1832. https://doi.org/10.1111/cogs.1262

CREATING A STUDENT-CENTERED COLLABORATIVE LEARNING ENVIRONMENT IN A UNIVERSITY PHYSICS CLASSROOM

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The time-honored conventional lecture ("teaching by telling") has been shown to be an ineffective mode of instruction for introductory physics classes. For enhancing critical thinking skills and developing problem-solving abilities, collaborative group-learning environments have proven far more effective. At George Washington University, we initiated a collaborative group-learning pedagogical approach (SCALE-UP) for classes in 2008. Since 2013, our introductory physics sequence has been taught exclusively in this mode, eliminating the "standard" lecture format, and this approach has been demonstrated empirically to yield higher gains in student learning.

In SCALE-UP, students sit at tables in groups of three, collaboratively performing various pencil/paper exercises (ponderables) using small whiteboards and engaging in hands-on activities like demos and labs (tangibles). Direct instruction (*i.e.* formal lecture presentation) is reduced to a minimal level, and the instructor serves more as a "coach" to facilitate the academic "drills" that the students are working on. This innovative pedagogy often arouses the curiosity of physics faculty, who wonder how the small-group format is organized and what activities constitute a typical class session. This workshop will answer these questions and will provide examples that can be implemented in your own classrooms.

This workshop is intended to be an active-engagement experience for all participants. We introduce student-centered learning environments and discuss challenges that might arise. Participants will then work together on several exercises illustrating the possible range of group-learning activities suitable for calculus-based introductory courses. Participants will learn how to develop and implement various hands-on and "minds-on" activities for their students in a collaborative pedagogical approach.

Workshop activities will include:

- Conceptual "clicker" questions.
- Whiteboard exercises consisting of conceptual or numerical problems.
- Group quizzes using "lottery ticket" scratch-off cards.
- Short hands-on exercises involving tangible manipulation.

The focus of the workshop will be on the in-class delivery of the exercises and the pedagogical value of the collaborative activities. The primary aim is for participants to experience this from the student perspective, which is necessary to fully appreciate the benefits of interactive engagement. The workshop is intended to demonstrate the feasibility and advantages of the collaborative group-learning approach and to inspire the workshop participants to implement such pedagogical reforms at their local institutions.

SENSORS, MICRO-CONTROLLERS: HOW DO THEY CONNECT

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Students graduating from the Applied Physics department of the Hague University of Applied Sciences are expected to tackle various problems. From understanding the physics behind an experiment to discussing the results with a manager. But also being able to use their time in the R&D lab space effectively. In our second year courses we teach Physical Computing [1] where students learn to combine both hardware and software in order to create something new. We ask them to create their own measurement platform based on a Raspberry Pi-Pico and provide subsets of task in order to guide them through the process. Students are free too use AI tools, but in the end need to answer questions without AI support.

The course has 4 distinct learning outcomes: connecting and using digital multimeters in the lab using Python scripts; choosing the right sensor based on the hardware requirements, focusing on the span of the analogue-to-digital converter (ADC), the word-length of the ADC (number of bits) and the measurement resolution; controlling 2 different available sensors and actuators; and being able to build, test, and use a measurement system combining sensors with input buttons and a small LED-screen. For each learning outcome there is a small assessment where the students show their skills with a 5 performance level rubric to assign their score. The assessment is there to test the student their skills, not the (AI) tools they used in order to complete the task.

In this workshop we will focus on sensor measurements. You will get access to materials and hardware. We will apply the following rubric:

30pt: The student can control different sensors using different interfaces and can store measured data in a meaningful format. The code is well documented and sensors are optimally utilized using supplemental electronic hardware (implemented or worked out on paper).

25pt: The student can control different sensors using different interfaces and can store measured data in a meaningful format. The code is well documented.

20pt: The student can control different sensors and stores measured data in a meaningful format. The code is well documented.

10pt: The student can control different sensors and stores measured data in a meaningful format.

0pt: The student cannot control a sensor.

During the workshop we will guide you through the process of working with the sensors and help you understand the joy of creating something yourself. After the workshop you have the tools to implement a Physical Computing topic and have access to the world of micro-controllers with micropython.

[1] M. Przybylla, R. Romeike (2014). Physical computing in computer science education. ACM Other conferences. https://doi.org/10.1145/2670757.2670782

MANIM IN PHYSICS TEACHING

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USING RESEARCH-BASED INSTRUCTIONAL MATERIALS TO FOSTER CONCEPTUAL UNDERSTANDING: TUTORIALS IN INTRODUCTORY PHYSICS

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Research on the teaching and learning of physics has identified specific conceptual and reasoning difficulties that often prevent students from developing a functional understanding of various topics taught in introductory physics courses. There is evidence that instructional materials that take into account such difficulties and prompt students to critically assess their own understanding can improve student learning.

This workshop will introduce participants to Tutorials in Introductory Physics [1] a set of materials intended to supplement the lecture, textbook, and laboratory of standard introductory physics courses for students in physics, engineering, and other fields. The *Tutorials* consist of cooperative-group worksheets to be used in synchronous (face-to-face or online) teaching environments and corresponding homework tasks. Each worksheet is preceded by a pretest that assesses students' prior knowledge and understanding about the respective topic. Instructors' materials also include notes on aspects that students may find particularly challenging as well as sample examination questions to assess student learning.

The *Tutorials in Introductory Physics* [1] were originally developed by Lillian McDermott and the Physics Education Group at the University of Washington (USA) on the basis of more than ten years of research on student understanding in introductory physics. The *Tutorials* have been translated from English into other languages, including Spanish, Greek and German. Moreover, they served as a model for the development of instructional materials for other STEM subjects, such as electric circuits, engineering mechanics, fluid dynamics and engineering thermodynamics, as well as specific topics in mathematics.

In addition to providing hands-on experience with the instructional materials, we will discuss various aspects of incorporating the Tutorials into an introductory physics course and present data from a large study to assess their effectiveness. Moreover, we will report on recent developments in translating and extending the *Tutorials* to other academic fields. Participants are invited to reflect on the feasibility and merit of *Tutorials* in an age of widespread student use of AI.

Further topics to be discussed in the workshop are:

- the need to address conceptual difficulties,
- the research base underlying the development of the *Tutorials,*
- the assessment of the effectiveness of instructional materials,
- some practical aspects of implementing *Tutorials* in various course formats,
- productive ways to combine *Tutorials* with other interactive teaching methods.

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HANDS-ON CRITICAL MAKING: ADDRESSING DISINFORMATION THROUGH STEM MAKERSPACES

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Makerspaces and Making activities have recently attracted increasing interest in education, particularly at school and higher education levels, due to their potential to foster digital competences and 21st-century skills through self-directed, project-based learning activities. However, concrete pedagogical approaches, procedures, and processes for systematically integrating critical thinking into making activities have not yet been explored sufficiently. The Erasmus+ Forward-Looking project *Critical Making – Addressing Disinformation in STEM through Makerspaces* aims to address this gap by designing and piloting approaches that combine Making with the purposeful integration of digital tools and Critical Thinking. The project develops concepts based on project-based learning (PBL) in pedagogical makerspaces and explores how such environments can be used to address disinformation while promoting digital competences in STEM in a comprehensive and hands-on manner through Making and the use of innovative digital technologies and tools.

This hands-on workshop is planned for 90 minutes and combines case studies, guided making activities, and collaborative reflection to reimagine how critical thinking can be promoted through making. It gives pre-service and in-service teachers an insight into and demonstrates how Critical Making can be meaningfully integrated into their STEM teaching practice as an approach to active, creative, project- and inquiry-based learning. The participants will work within a scenario framed as a sustainable city of the future and explore physical solutions to different challenges that such a scenario may entail. Using simple, easily available materials, they will build prototypes that serve both as potential solutions and as conversation pieces for a concluding discussion on critical thinking with a STEM perspective.

During the workshop, participants will be guided through the framing of a sustainable city of the future and offered different choices of tools, materials, and topics to create and explore, supported by the workshop facilitators. Examples include prototyping with simple materials such as cardboard, experimenting with AI robots, and tinkering with 3D modelling. These activities model innovative practices in STEM education that teachers can readily adapt to their own classroom contexts. The workshop is structured as follows: First, we give a short introduction into Critical Making as a pedagogical platform that bridges STEM, Critical Thinking, inquiry, and hands-on experimentation, anchored in relevant research. This is followed by several maker activities, including (1) working on a selection of hands-on "Critical, Making, Informative (CMI)" projects, each accompanied by a description card; (2) an introduction to and guided practice with Design Thinking and low-threshold prototyping using simple materials in a science-centre context; and (3) an approach to working with AI robots as tools for student innovators who design concepts for autonomous urban mobility. The workshop concludes with a collective reflection on disinformation in science and on how to promote scientific literacy, Critical Thinking, and digital competencies through Making.

APPLICATIONS OF A SPATIAL LIGHT MODULATOR IN THE UNDERGRADUATE OPTICS LABORATORY

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Spatial light modulators (SLMs) are optoelectronic devices that enable dynamic modulation of the amplitude or phase of a laser beam. They are widely used in research areas where manipulation of the spatial phase of light is required, including laser beam shaping, microscopy, and optical computing.

The key component of an SLM is a liquid crystal display (LCD) consisting of a pixelated layer of liquid crystals. Liquid crystals exhibit properties characteristic of both liquids and crystalline solids. In particular, they combine long-range molecular ordering, typical of crystalline materials, with the ability to flow, characteristic of liquids. The orientation of liquid-crystal molecules affects the propagation of polarized light, allowing the polarization state of transmitted light to be modified. Moreover, the molecular orientation can be controlled by an applied electric field. As a result, the voltage applied to each pixel locally modulates the intensity, phase, or polarization state of the transmitted light. Because the SLM matrix can be readily controlled by a computer, this approach enables real-time manipulation of the optical wavefront.

In this work, we demonstrate how spatial light modulators can be implemented in undergraduate laboratory settings. Several exemplary optics experiments suitable for instructional laboratories are presented, including single- and multiple-slit diffraction, implementation of a Fresnel lens, polarization effects, and optical Fourier transformations. Finally, we show that, by employing amplitude holography, the device can also be used to generate structured light beams.

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AI-SUPPORTED PROBLEM SOLVING AS A CATALYST FOR INNOVATION IN PHYSICS EDUCATION

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Artificial intelligence (AI) offers a wide range of possibilities in contemporary education. When confronted with challenging problems, many students consult AI systems, pose a question, and simply read the generated response. They often assume that the provided solution is correct. However, an important question arises: do students critically evaluate the validity of these answers? My experience as a physics teacher indicates that although AI systems can generate solutions to physics problems rapidly—often instantaneously—their responses are not always accurate.

This presenation examines the responses produced by several AI systems to a question posed by students to AI during a physics lesson: "*What is the average power of a cat that jumps 1 meter high, assuming the cat has a mass of 4 kg?*" Different AI tools provided different numerical results, highlighting inconsistencies and suggesting that not all AI-generated solutions were reliable. Poster presentation will allow comparison of individual AI models.

To verify the correctness of these responses, students conducted a video analysis of a cat's jump using the Tracker software. This analysis confirmed the accuracy of one AI-generated solution while disproving the correctness of another. Video analysis in Tracker represents an interactive, inquiry-based approach that aligns with the "analysis" level of Bloom's taxonomy [1-3]. Through mathematical and graphical examination of motion data, students determined the relevant physical parameters and independently derived the correct answer to the problem.

The findings presented in this article underscore the importance of critically evaluating AI-generated solutions. Particularly in physics and mathematics, where correctness depends on conceptual understanding, appropriate modeling, and precise numerical reasoning, students must verify and analyze AI outputs rather than accept them uncritically. When doubts arise, the problem can be reformulated or specified more precisely for the AI tool; however, final verification remains essential. Ultimately, it is the student's responsibility to assess whether the AI's solution is valid or whether an alternative reasoning path is required.

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DESIGNING AN ASYNCHRONOUS INTRODUCTORY PHYSICS COURSE: INTERACTION, LABS, AND ACADEMIC INTEGRITY IN ONLINE EDUCATION

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Online courses are often criticized for limited engagement and perceived lower instructional quality compared to in-person offerings, yet student demand continues to grow. We describe the design and implementation of a first-semester introductory Physics course developed for a fully asynchronous, intensive 6-week summer term at a large research-intensive public university.

The course was structured to promote meaningful interactions among students, instructors, and course content. Student–content interactions were supported through instructor videos, slides, an e-book, an online laboratory platform, and an online homework system. Student–instructor interactions included weekly discussion board posts on the learning management system (LMS) and group office hours. In addition, synchronous office hours held twice per week, along with consistent instructor feedback on assignments, emails, and LMS messages, further strengthened student–instructor engagement.

Principles of Universal Design for Learning were integrated to support accessibility and inclusivity. A central challenge – the laboratory component – was addressed by implementing authentic, hands-on experimental activities adapted for remote learning. Students purchased laboratory kits from a vendor that provided all the necessary equipment to complete the course's ten laboratories and carried out the activities through the vendor's online platform. They submitted photos of their laboratory setups, completed data tables, and responses to questions within the platform. Instructors were able to access and grade students' laboratory submissions directly there.

We ran the course for the first time this past summer. Demand for the online section exceeded our expectations, with the course filling (20 students) on the first day of summer registration and requiring us to open a second section, which nearly filled as well. By comparison, the in-person summer section had about one-quarter as many students. Student performance was on par with that of the in-person section. However, the online section had a higher drop rate, especially during the first two weeks. In addition, students often struggled even more to manage their time in an asynchronous online course, so clear communication through frequent course announcements was critically important. Strong course organization and structure were equally important in addressing this.

We also outline strategies used to promote academic integrity in the online environment. All quizzes and exams were completed using a live proctoring service, where students scheduled individual exam time slots. Numerical problems included randomized values for certain variables, and problem pools were used to generate different quiz versions. Students were required to upload images of their handwritten work for all questions, including multiple-choice items. Because lab activities were hands-on, students collected real data, which helped deter data sharing.

FLEXIBLE LEARNING AND ASSESSMENT IN ENGINEERING PHYSICS

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Students sometimes perceive the engineering physics courses as abstract and disconnected from professional practice. At the same time, increasingly diverse student cohorts, including Finnish- and English-language degree programmes, require more flexible and inclusive instructional designs. This paper presents a course implementation that combines modular learning pathways, strategic assessment, and application-oriented content.

The course "Engineering physics 2" consists of eight topics organised into a branching structure. A mandatory foundation in quantum physics is followed by two thematic branches: (A) radiation and nuclear physics, and (B) semiconductor physics. In addition, two independent topics: sound and acoustics, and energy efficiency in buildings, focus on workplace-relevant applications. Students freely choose their learning paths beyond the core, supporting autonomy and motivation [1]. This is the third year this course has been implemented, and the course structure and covered topics included have evolved along the way. Course attendance has increased each year, and this has raised demand for a broader selection of topics and a more elective course structure.

Assessment is designed to encourage broad engagement. The final exam includes eight questions (one per topic), from which students answer four. The possibility to choose reduces performance pressure and supports mastery-oriented learning in line with assessment-forlearning principles [2] and constructive alignment [3]. The assessment only requires studying half of the topics offered in the course, but students have the option to study more if they have an interest in doing so.

The pedagogical approach combines lectures with small-group measurement, modelling, and project work. The project component allows students to pursue experimental, simulationbased, or literature-based investigations on topics of their choice. Regardless of format, projects require a clear theoretical background, methodological description, analysis of results, and justified conclusions. This structure strengthens the connection between theoretical physics and real-world applications while supporting active learning practices [4].

As the course is currently ongoing, systematic data is not yet available. Initial observations suggest that students make diverse, interest-driven topic selections and engage broadly with course content.

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GRASPING MEASUREMENT UNCERTAINTY: EVALUATING A PROJECT-BASED INTRODUCTORY PHYSICS LAB FOR MEDICAL PHYSICS STUDENT

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Proficiency in handling measurement uncertainty is a core competency in engineering and applied sciences, yet first-year students often struggle with its conceptual foundations. This contribution presents a project-oriented introductory physics and metrology lab developed for the Medical Physics undergraduate program at the Berlin University of Applied Sciences and Technology (BHT). Moving away from traditional "cookbook" experiments, the module emphasizes self-directed projects – such as 3D-printing-based component testing or the performance analysis of projectile launchers – where the practical application of the Guide to the Expression of Uncertainty in Measurement (GUM) [1] is central.

To evaluate student learning, the Physics Measurement Questionnaire (PMQ) [2] was administered in a pre-post-test design. The results indicate a significant conceptual shift from the error-focused "point paradigm" toward the scientifically grounded "set paradigm." While the observed learning gain is consistent with international literature on similar interventions [3, 4], the study identifies data comparison as the most persistent challenge for students. This contribution discusses the benefits of the project-based approach, shares qualitative student feedback, and outlines strategies for further optimizing the didactics of measurement in foundational physics labs for engineering students.

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HOW EXCEL CAN HELP YOU SOLVE PHYSICAL PROBLEMS

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MS Excel is a very useful tool for engineering calculations. Students usually use it to prepare laboratory reports. Hence, students know at least the basic functions of MS Excel. Additionally, MS Excel is widely available thanks to educational licenses.

The standard procedure students use to solve the physical problems is as follows… They use physical laws and transformations of formulas (mathematical knowledge and competencies are essential). Finally, they derive the formula for the required physical parameters. The last step is to check that the derived formula makes physical sense.

I want to suggest changing this standard procedure sometimes… Instead of transforming formulas, numerical calculations should be used. But the calculation (typical of numerical procedures) of the final value of the parameter being sought is not sufficient. The physical problem is fully solved when we know the analytical formula for how the required parameter varies with the conditions… Using MS Excel, we can not only calculate the final parameter but also derive the analytical formula for the searched parameters.

MS Excel can help solve some physical problems that lead to integration or differential equations. We know that integration is nothing more than summing up. MS Excel is good at summing cell contents. We also know that differential equations can be solved step by step [1]. It leads to the discretisation of differential equations.

I will present one example of a physical problem to solve: How to find the formula for electrostatic force $F(x)$ between a point charge $-q$ and a homogeneously charged with charge $+Q$ stick (see Figure)? This problem can be solved analytically, so the results of numerical investigations are easy to verify…

In this example, we also use a special tool implemented in MS Excel: Solver. It is a tool for multi-parameter optimisation and can help find parameter values that satisfy the problem assumptions.

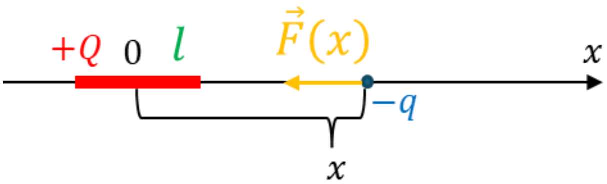

Figure. Homogenously charged $(+Q)$ stick with length l. Distance between the point charge $(-q)$ and the centre of the stick is x.

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HYBRID SCALEUP ROOMS: TURNING ONLINE PARTICIPANTS INTO ACTIVE IN-PERSON PARTICIPANTS

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Unlike traditional teacher-centered lecture halls, students in a SCALE-UP (Student Centered Activating Learning Environment for Upside-Down Pedagogies) room [1,2] sit at group tables, thus focusing on student collaboration and placing the instructor in the role of a decentralized learning coach. This SCALE-UP concept, which was developed for face-to-face teaching in a classroom, is challenged by the general desire of students for more flexibility in terms of space. A well-established approach for more flexibility is "hybrid teaching” i.e. teaching that enables synchronous online participation via video and audio transmission. However, this approach carries the risk of destructive passivity among those students who participate online [3]. The concept of a hybrid SCALE-UP room presented here aims to provide online students with a learning environment that ideally matches the environment in the classroom in terms of activation, feedback, and ultimately, learning success. The group tables in the new hybrid SCALE-UP room at Albstadt-Sigmaringen University are equipped with an interactive touchscreen and a 180° video and audio system, giving online and in-person students the experience of sitting together at the same table. Each table also has a mobile pen display, allowing online and in-person students to collaborate on a digital whiteboard, the content of which is always visible to all group members on the interactive touchscreen. This setup eliminates the need for personal devices, keeping the focus on collaboration. A formerly developed teaching concept [4] has been adopted and improved for the hybrid SCALE-UP Room, which allows for more flexibility in terms of time and space without significantly limiting learning outcomes for online participants. Initial results regarding learning outcomes and student feedback are very promising and will be presented. Feedback from students showed that the typical barrier in communication between online and face-to-face students has been successfully removed. Furthermore, the negative correlation between the proportion of online participation and relative success in the course appears to have weakened since the introduction of the new hybrid SCALE-UP room.

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INTEGRATION OF AI-TOOLS INTO A PHYSICS LABORATORY COURSE

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This paper presents the integration of AI-supported systems into a physics laboratory course at HTWG Konstanz in the summer semester 2025. The lab was conducted using the LabTeamCoaching approach [1]. Students were asked to use general-purpose AI models to prepare for the laboratory experiments. In addition, AI was used to provide feedback on students' lab reports before they were submitted to the instructor.

The focus is on two key moments in the LabTeamCoaching approach:

- *AI-supported preparation*: Can students prepare themselves for lab experiments just as well – or even better – with general-purpose AI models as with traditional textbooks?
- *AI feedback on lab reports*: Can an AI system automatically provide high-quality feedback that improves reports and supports learning processes without replacing instructors?

Survey results show active AI use by students, who largely perceive the use of AI as helpful. General-purpose AI models can provide valuable support in teaching without requiring specific customization or training – at least when dealing with topics that are already well represented in the AI models (such as classical physics topics). However, the availability of higher-quality, paid versions of AI models raises questions about educational equity and the development of AI literacy.

The paper presents details from the investigations regarding the implementation and objectives of the lab, the scope and intensity of AI use, as well as the results and conclusions drawn from the surveys. However, the study provides only an initial assessment, as no direct comparative study has been conducted.

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DEVELOPMENT OF VIRTUAL REALITY RADIATION LAB TO STRENGTHEN RADIATION SAFETY AWARENESS IN UNDERGRADUATE STUDENTS

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Radioactivity, the spontaneous disintegration of atomic nuclei, is invisible and its effects are not directly perceptible (odourless, intangibility). Therefore, radioactivity must be handled with a particular care to prevent harmful health effects.

In the Physics Laboratory courses of the undergraduate programmes at the Faculty of Science and Engineering, approximately 200 students each year work with various radioactive sources while conducting experiments independently. Although students receive both theoretical and practical instructions in radiation safety, observations indicate that safety protocols are not always consistently followed by students during handling of the radioactive sources.

To enhance students' understanding of radiation and its associated risks, an engaging Virtual Reality environment, the "Virtual Radiation Lab", is being developed. The platform allows students to practice safe handling of radioactive sources, distance effects and shielding properties in real time.

The educational goal is to bridge the gap between theory and practice. Integrated prior to hands-on experiments, the VR experience aims to strengthen conceptual understanding, enhance risk awareness and promote responsible laboratory behaviour of students in physics and applied physics courses.

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THE DEVELOPMENT OF AN EDUCATIONAL MEASUREMENT SYSTEM TO BRIDGE THE GAP BETWEEN MEASUREMENTS ON GRAPHENE MICRODEVICES AND UNDERSTANDING THE UNDERLYING CONCEPTS

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Graphene – a single atomic layer of graphite – is discovered experimentally at the University of Manchester in 2004 [1]. Graphene exhibits extraordinary electronic properties that are distinct from graphite. This opened the research field of 2D materials, and led to the Nobel Prize of Physics for the pioneers Andre Geim and Konstantin Novoselov in 2010 [2]. Graphene is not only a fundamentally interesting material system, but also a promising material for applications in microchips, flexible electronics, electro-optical sensors, biosensors, and possibly future field-effect transistors [3-4].

At The Hague University of Applied Sciences, we are currently developing an educational measurement setup for electronic measurements on electrostatically gated graphene microdevices. This will enable undergraduate bachelor students Applied Physics to study graphene's unique electronic properties, and how its electrical resistance can be controlled by electrostatic gating. This will help students to learn the concept of field-effect transistors, and to characterize charge transport properties of graphene in relation to graphene's unique band structure.

In this poster presentation, I will provide an overview of the design of the educational measurement system, and I will show the current status of its realization. Moreover, I will give examples of learning objectives that undergraduate bachelor students Applied Physics can address by designing and performing experiments with this educational measurement system. For instance:

(i) 2nd and/or 3rd year's undergrads can study the Drude model and apply this theory on their electronic measurement data to determine electron and hole mobilities of graphene microdevices at room temperature.

(ii) 3rd and/or 4th year's undergrads can study the theory of graphene's band structure and charge scattering mechanisms, and explore the manifestation of charge transport in graphene by performing electrical experiments on graphene microdevices at room temperature.

These examples may initiate further discussions on how this educational measurement setup can enable students to enhance their experimental skills on microdevices as well as strengthening their understanding of the related underlying physical concepts.

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A RESEARCH-ORIENTED PHYSICS WORKSHOP AS AN ALTERNATIVE TO METROLOGY AND INTRODUCTORY PHYSICS LABORATORIES

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Teaching the principles of scientific experimentation and metrology is a core component of engineering physics education. For many years, this training at the Faculty of Physics WUT has been delivered through two independent courses: an experimental data analysis course and a typical introductory physics laboratory. The first emphasized calculations based on hypothetical datasets and uncertainty evaluation, while the second focused on performing predefined laboratory exercises (according to strict instructions) and preparing formal reports on them. Conducted separately (and, surprisingly, in different semesters), these courses offered limited scope for creativity and failed to effectively develop essential engineering competencies and to train experimental physicists. Moreover, the introductory physics laboratory, constrained by a fixed set of predefined experiments, provided little opportunity for engaging students in physics didactics or authentic research practice (due to the limited number of experiments and the lack of any possibility for modification).

To address these limitations, a new practical, integrated course was introduced. Its aim is to familiarize students with the complete methodology of experimental research in physics and engineering, including hypothesis formulation and verification, experiment planning, direct and indirect measurements, uncertainty analysis, and effective data presentation. These skills are developed through workshop- and project-based activities grounded in real-life and experimental problems.

The course includes an extensive practical component, in which small student groups conduct a specific number of experiments across various branches of physics (e.g., solid-state physics, optics, nuclear physics). Importantly, students receive only a list of relevant physical principles and instrumentation manuals in advance (i.e., prior to the lab session), encouraging independent problem-solving and experimental design. Each group carries out experiments selected individually at the start of the semester, including at least one randomly assigned experiment and one fully student-designed project involving proposal development, experimental realization, and results presentation (9-12h).

Additional course elements include: (i) peer review and discussion of other teams' reports and (ii) oral presentations of experimental results, and collaborative experiment development and realization (related to randomly assigned problem and to the project proposed by the student teams).

Overall, this integrated, practice-oriented approach has demonstrated a positive impact on students' understanding of experimental research methodology, as well as on their ability to analyze, interpret, and communicate scientific results. Knowledge acquired through creative and hands-on activities is more durable and transferable, supporting further university education and in potential research and academic work in the future.

AI IN STEAM EDUCATION: DEVELOPING CRITICAL UNDERSTANDING AND AI LITERACY AMONG LEARNERS

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Over the last few decades, we have witnessed an unprecedented technological revolution that has deeply impacted our everyday lives and work. This revolution was largely driven by: computerization, Worldwide Connectivity, mobile communications, and, most recently, AI, which is likely to be the most impactful of all the technologies mentioned earlier. These developments create both opportunities and challenges for education in general and for physics teaching in engineering education, where students are increasingly expected to use AI-supported tools critically, responsibly, and effectively for modeling, data analysis, experimentation, and problem-solving. Developing AI literacy has become an important element of modern STEAM education.

The ongoing AI2Schools (https://ai2schools.fizyka.pw.edu.pl/) Erasmus+ KA2 project focuses on integrating and implementing AI into STEM secondary school education through the STEAM approach. The main target group is secondary school educators and learners, including potential candidates for higher education studies. AI2Schools' results include documents, online courses, training materials, learning scenarios, and hands-on AI projects:

- AI curriculum Teacher Handbook – describes the methodology of AI application in formal and informal settings, and helps teachers introduce AI literacy to their students,
- Two AI hands-on projects that teachers may replicate during their lesson: These are the "AI body-beats" project, which utilizes the BBC micro:bit & the micro:bit Create AI Machine Learning environment and introduces AI through gesture recognition and music, and the "Visual Lab" project, which makes abstract mathematical concepts visible and dynamic,
- An open Moodle AI course enhanced with quizzes and assignments, and 3 webinars for teachers and educators.

[1] D. Long and B. Magerko, (2020). What is AI literacy? Competencies and design considerations. Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems, 1–16. https://doi.org/10.1145/3313831.3376727
[2] D. T. K. Ng, J. K. L. Leung, S. K. W. Chu and M. S. Qiao (2021). Conceptualizing AI literacy: An exploratory review. Computers and Education: Artificial Intelligence 2, 100041. https://doi.org/10.1016/j.caeai.2021.100041