GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN IN PUBLICA COMMODA SEIT 1737

ENLIGHT

Application: ENLIGHT Teaching and Learning Award 2024

Course title: Experimentalphysik 1 (Experimental Physics 1)

Course summary (max 200 words):

Experimental Physics 1 is the fundamental introductory physics course for first-semester physics students (major and teacher training). It covers essential concepts and principles of classical mechanics and thermodynamics, providing the foundation for more advanced studies in physics. Lecture demonstration experiments play a central role in illustrating theoretical concepts and deepening students' understanding. These experiments serve to practically demonstrate and explain the physics laws and phenomena discussed in the lectures. The lecture is supplemented by weekly exercises (so-called recitations) and tutorials that reinforce the material and promote the application of learned concepts in problem-solving tasks in small student groups. Typically, students work on problem sets, submit them for correction, and discuss them with tutors.

Content-wise, the course begins with the study of point masses (kinematics, dynamics) and increases in complexity: point masses with interactions (e.g., collision), rigidly connected point masses (rigid bodies), relaxing the rigidity condition (solids), many-particle systems (fluids, hydrodynamics), oscillations and waves, as well as the basics of thermodynamics.

The goal of the lecture is to provide a fundamental understanding of physics concepts and their mathematical descriptions, to develop analytical skills and problem-solving strategies, and to prepare students for advanced topics in experimental as well as theoretical physics.

All educators involved

Prof. Dr. Pascal Klein (Head, contact person*): Lecture
Joachim Feist: Lecture demonstration experiments
Dr. Larissa Hahn (Senior assistant): Head of recitations, exercise sheets, organization/coordination
12 student assistants (recitation groups):
Dominik Patrik Benz, Sören Jon Beyersdorf, Vincent Christoph Brockers, Robin Cedric Danek, Konrad Raimund Göllinger, Michele Denis Kellermann, Annika Korn, Sune Kühne, Lukas Melzig, Felix Ben Müller, Malte Andrés Probst, David Arthur Ramcke

Simon Z. Lahme (Physics education researcher): implementation and evaluation of innovative smartphone-based undergraduate research projects, stress monitoring
Lefkothea Sinjari (International Writing Lab): co-design of a workshop accompanying the undergraduate research projects
Merten M. Dahlkemper (Physics education researcher): implementation and evaluation of chatGPT responses to physics questions (“spot the bot”)
Carlo von Carnap: manim animations

Prof. Dr. Gerhard Hegerfeldt (theoretical physicist): additional voluntary tutorial
Number of students enrolled in the course: **254**

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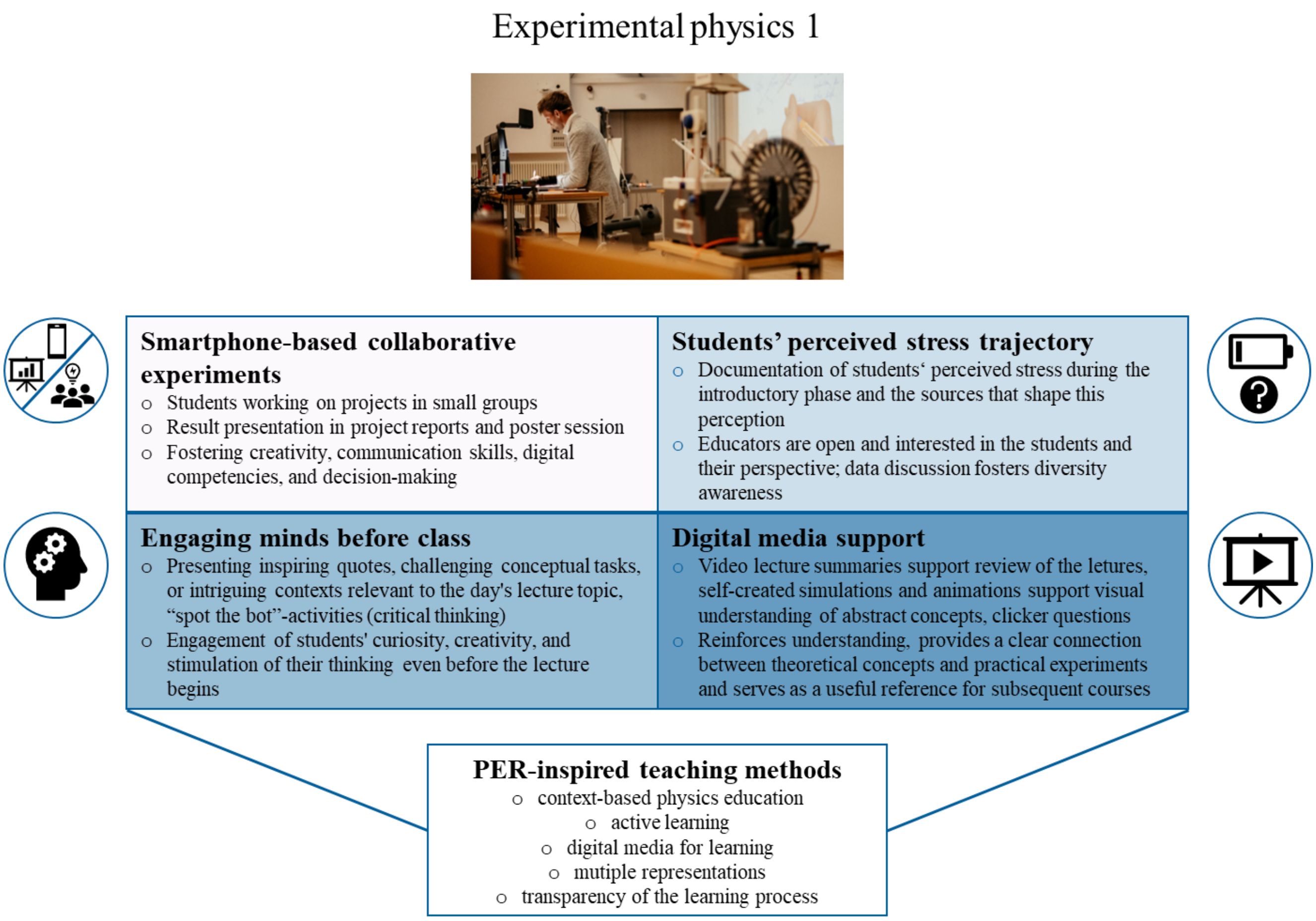
Experimental physics 1 – Portfolio (2-4 Pages)

Experimental Physics 1 (PHYS 1) is a standard course in almost every physics study program with a wealth of traditional materials available. However, it is well-documented and supported by Physics Education Research evidence that conventional teaching methods can be ineffective. In winter semester 2022/2023, the course was organized by Prof. Dr. Pascal Klein and his Physics Education Research team. Their approach focused on student learning, incorporating innovative pedagogical strategies, both in the lecture and recitations, and technological tools to enhance interactivity and creativity in instruction (see below). Additionally, the stress levels of the students were measured weekly, creating a stress trajectory that provides learners and instructors with insights into the current state and sources of stress.

The students in the evaluation praised the lecture style (slow-paced) over the fast-paced slide presentations that are typically used. They also appreciated the inclusion of a practice exam and the well-organized structure of the course. From the beginning, an overview of the lecture topics was provided, including references and connections to exercise tasks. The lectures referenced individual exercise tasks, and demonstration experiments were documented. While these are not groundbreaking innovations, they also contributed to the success of the lecture. The overview and examples of the notes are linked here: https://owncloud.gwdg.de/index.php/s/BeLyQGFDnZz597V

Overview of the key innovations:



The following sections describe the key innovations of the course in more detail.

Innovation 1: Smartphone-based undergraduate research projects *(cf. ENLIGHT challenge-based education principles "Collaboration" and "Innovation & Creativity")*

Undergraduate research projects (URP) were implemented into the PHYS 1 recitations to foster students' affections like curiosity, interest, and sense of belonging to the university and study program as well as to provide opportunities for self-regulated inquiry-based learning. In groups of four, students worked on one out of six experimental tasks that not only reinforced various lecture contents but also emphasized the social, communicative, and emotional aspects of scientific research, thus reducing the attribution of physics as purely objective and emotionless. The built-in sensors of the students' smartphones and household items enabled students to flexibly conduct their experiments and collect digital first-hand data in everyday situations. The tasks are open-ended to allow students to be creative and to encourage critical discussions, problem-solving, and decision-making among students. An example: Have you ever noticed that a standing elevator cabin starts to oscillate if you (carefully!) jump in it? Using the acceleration sensor of a smartphone, the frequency of the oscillation can be measured. You will find that this frequency depends on the floor you are on (because the cable length above the cabin varies), and with a bit of theory, you can estimate the building height after a few measurements.

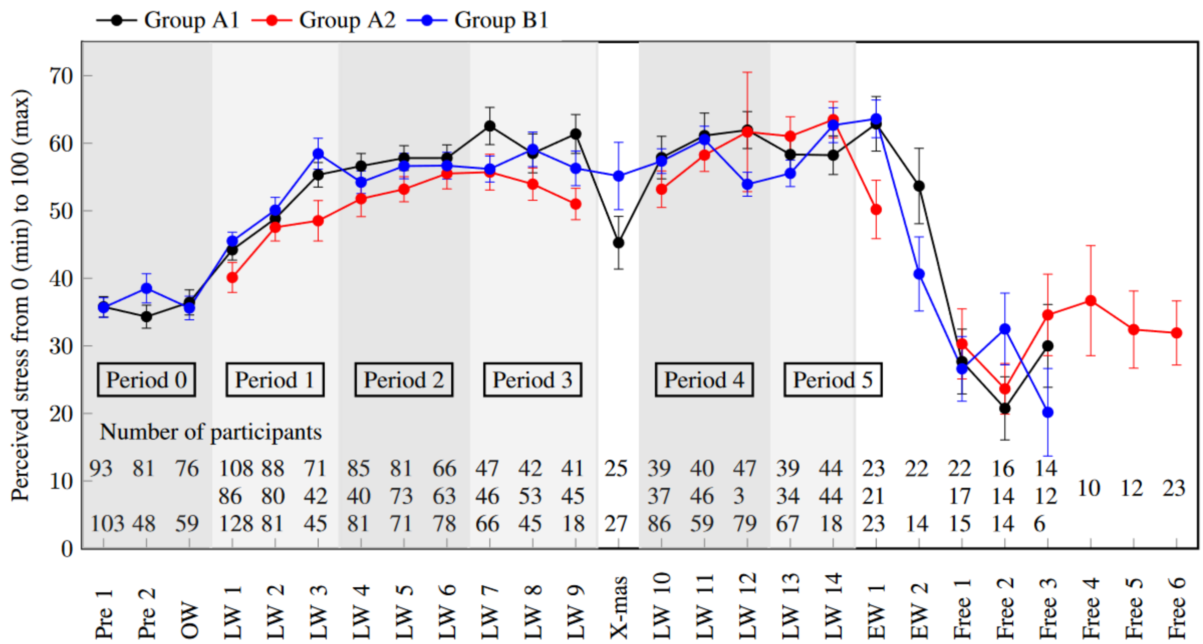
Students worked on their URP self-directed but still guided by various supportive measures for two months. They presented their findings among peers and faculty in a structured poster session promoting the presentation of subject content and the use of correct scientific language. Finally, they reflected on their project work following guiding questions in written form. Posters and responses to the reflection questions were assessed; feedback was provided to students.

The URP was evaluated by several questionnaires. The analysis is in progress and a scientific manuscript is in preparation. An initial analysis of open text field responses reveals that the students liked the opportunities for autonomy and creativity as well as the collaborative group work. The students expressed a sense of accomplishment and growth in their competencies through their participation in the project. They appreciated the opportunity to easily investigate everyday phenomena using readily available household items and smartphones.

The task design and the implementation are described in this manuscript: www.doi.org/10.1088/1742-6596/2693/1/012008. All materials are available as Open Educational Resources (OERs) in German and English and can be reused by other lecturers in their teaching: https://doi.org/10.57961/49zr-w490.

Innovation 2: Students' perceived stress trajectory *(cf. ENLIGHT challenges "Health and Well-being" and "Equity")*

As very high dropout rates indicate, many students perceive the introductory phase of a physics program as challenging due to the need to manage demands on multiple levels (academic, metacognitive, and social) to transition from high school to university successfully. This phase can often lead to stress perceptions due to a mismatch between university demands and personal resources to cope with the demands. In PHYS 1, an investigation was implemented on how physics students perceive stress across the introductory phase and which stressors cause this perception. Data was collected using standardized instruments during a 5-minute break in the lecture every week. This generated a perceived stress trajectory for that cohort of students (group B1) that could be compared with data from the previous cohort (groups A1 & A2). It was found that both cohorts reported very similar stress perceptions throughout the semester revealing high stress levels during most of the lecture time and primary stressors.



The students greatly appreciated that faculty showed interest in their perspectives and needs through these surveys. This was reflected not only in the high willingness to regularly participate in the survey but also in the sometimes very personal comments in the open text sections of the surveys. To initiate a dialogue, from time to time, students were shown the current findings. This led to mutual discussions about topics such as mental health, the inclusive design of the study program, student satisfaction, academic success, and preventing dropouts. The study outcomes provide a substantial empirical basis for the future development of supportive measures to mitigate high stress levels and reduce dropout rates for upcoming generations of students. Curious? See this preprint: https://doi.org/10.48550/arXiv.2404.05682.

Innovation 3: Engaging minds before class

At the beginning of each lecture, an introductory slide was presented 15 minutes before the session started, as students gradually entered the lecture hall. This slide featured inspiring quotes about learning, a conceptual task provided by physics education research, or an interesting context relevant to the day's lecture topic. For example, one of the slides read: "Speed SkyDiving is probably the fastest non-motorized sport. The picture shows the national team

'Fire' from Sweden in a four-person formation during training. Provide physics arguments why 'Speed SkyDiving' can be considered a sport." The purpose of these introductory slides was to engage students' curiosity and creativity, as well as to stimulate their thinking even before the lecture begins. By presenting inspiring quotes, challenging tasks or intriguing contexts, students are encouraged to connect with the material on a deeper level. This approach helps to set a positive and thought-provoking tone for the lecture, fosters a more interactive and engaging learning environment, and encourages students to think critically about the subject matter.

Sometimes, "spot-the-bot" activities were also used: Students were given solutions to physics problems from both ChatGPT and human experts. Their task was to determine which answer was the best in terms of language and content. In an accompanying study, we found out how important subject knowledge is for making accurate assessments: https://doi.org/10.1103/PhysRevPhysEducRes.19.010142 https://journals.aps.org/prper/abstract/10.1103/PhysRevPhysEducRes.19.010142

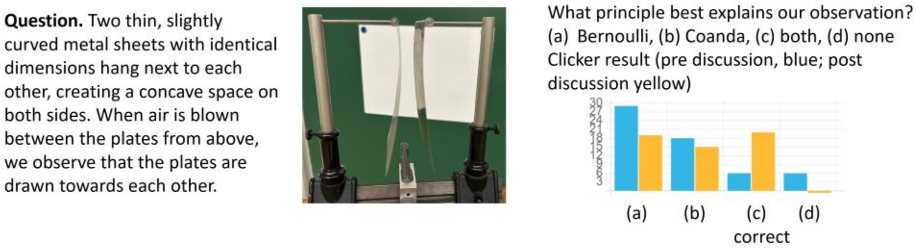
Innovation 4: Digital media support

i) The lecturer created concise **video summaries** of each lecture, approximately 15 minutes long, right after each session and made these videos available online. This approach is beneficial as it allows students to quickly recap the essential points, reinforces their understanding, provides a clear connection between theoretical concepts and practical experiments, and serves as a useful reference for subsequent courses. Youtube-Playlist:

https://www.youtube.com/playlist?list=PLGU9pyRMADhYxsjzgaEikhcgIUYARGqL3

ii) **Animations** can significantly aid in understanding complex physical phenomena by visually demonstrating concepts that are difficult to grasp through text and static images alone. Despite their potential, there are surprisingly few animations available for intricate topics in introductory physics. To address this gap, we created our own animations using **MANIM**. These animations help clarify and illustrate complex principles, making them more accessible and easier to comprehend for students: https://cvc97.github.io/Physics-Education-Animations/

iii) "**clicker questions**", i.e. interactive multiple-choice questions that students answer during lectures using handheld devices, were used to keep students actively involved during lectures. Instructors received instant feedback on students' understanding, allowing them to adjust their teaching to address misconceptions or difficulties. It was observed that student understanding improves significantly when they discuss their answers with peers and then vote again, benefiting from the process of peer instruction.



Official course evaluation data: https://owncloud.gwdg.de/index.php/s/qdl97puI7HPlCnE