I. Leitfragen für die Berichterstattung und Rückmeldung zu innovativen Lehrprojekten

1. Titel des Projekts, Ansprechperson(en)

Pilot project on building scientific apparatus: Starting students research experience at an early stage, PIs of the project: Dr. Micol Alemani und Prof. Markus Gühr.

2. Welche (Haupt-)Ziele wollten Sie erreichen?

Bitte benennen Sie die angestrebten Ziele, wie sie im Antrag standen, und schätzen Sie ein, ob die Ziele erreicht werden konnten. Bitte gehen Sie dabei auch darauf ein, ob (und wenn ja wie) die Ziele angepasst wurden.

We would like the students in the introductory physics lab to build their own measurement apparatus with simple means for at least one time. Usually, our students are using 'ready made' and computerized setups in the basic and especially the advanced practical classes. Although that cannot be changed in every context, we argue that few apparatus construction sessions serve multiple important points.

The goals of our project are:

1) Derive a measurement problem from a scientific question.

   Traditionally, a ready-made apparatus is available at the lab bench of a lab class. Students are not invited to use creativity in thinking about their own measurement strategies. The new format in the practical class devised by M. Alemani leaves space for free experimental procedures and data analysis, but introduces the aspect of apparatus building only with respect to very elementary instrumentation. In this project however, we intend to extend this approach towards building more complex experimental setups.

2) Inform about different measurement strategies for the problem.

   In this project, students will learn to use their theoretical knowledge in a very applied context. Designing measurement strategies means to model possible outcomes and comparing advantages of the different feasible approaches. One of the most important innovations is applying critical reasoning to seemingly similar strategies. Based on their knowledge, students deliberately decide to take risk and spend effort and time on the most promising approach.

3) Come up with a first approach to construct a setup, build it, test its performance and calibrate it.

   Traditionally, this task is always done by others for the students even if they have the freedom to choose between different *already existing* instruments. In our new approach, this particular point obviously takes most of the time but it also comes with most of the fun. Here students are learning important skills such as mechanical and electronic design, teamwork and communication as we will distribute specialized tasks in smaller teams.

4) Approach the scientific question with that newly developed setup.

   Finally, students will be able to harvest the fruits of their hard work. As always in science, things will not work as expected and this is a crucial part of the authentic research experience. We will guide our students to embrace this aspect of their apparatus building experience, as oftentimes failures have a higher learning effect as fast success.

5) Iteratively improve the setup.

   Here, our students will analyze problems with their setup, identify the parts that go wrong and substitute them by redesigned parts.

Our project was planned to take place end of March when students had several days spare time in the semester break. We had 10 students enrolled in the project. Unfortunately for that project, the university closed in order to avoid spreading CoViD-19. We therefore had to postpone the project by a so far unknown time interval. For this unexpected reason, we could not evaluate to this point how our learning goals were achieved.

3. Wie können diese Ziele in das zukünftige Leitbild Lehre der Universität eingeordnet werden in Bezug auf die Themen Forschungsorientierung, Tätigkeitsfeldorientierung und Persönlichkeitsbildung, interdisziplinäre und fachübergreifende Lehre, zielgruppenspezifische Lehre sowie Studierenden- und Kompetenzorientierung? Den aktuellen Entwurf des Leitbilds finden Sie unter
https://www.uni-potsdam.de/zfq/leitbildlehre/

This teaching/research project has very strong connections with following tasks of the Potsdam University (UP) teaching statement (TS):

Research orientation: The research orientation in the UP TS was stated as 'letting every student experience the full research process at least once, even in the Bachelor phase'. In fact, apparatus building in a physics lab class is a unique environment for experiencing and practicing the experimental research methods at the early stages of the curriculum. Quantifiers for 'real lab research' such as ambivalence with respect to the 'ideal method or instrument' and iterative approach to a problem can be experienced here in an authentic way, even before a research-oriented bachelor thesis.
In particular, in the TS, one of the measures for the realization of the 'research orientation' task is to integrate team-building in university courses. In our project, team work is a crucial aspect. In fact, students work in a 10-students team for coming up with ideas around how to build the best apparatus for a specific purpose. We then divide the group into sub-groups according to their personal preference and skills. Some students will find it interesting to care about the optics design and simulation, an aspect that requires theoretical knowledge and computational skills. Other students will most likely care about the mechanical aspects of the apparatus. For them we will have options to choose between optical breadboard or even 3D-printed custom housings for the spectrometer. Other students will most likely care about the detector, will write software to read it out, and might even write routines to compare the spectra with database information. Note that progress of each team is crucial to accomplish the full project. As one team comes up with more details in their sub-tasks, other teams will have to be informed for the full instrument to succeed. Teambuilding and teamworking aspects as well as structured communication and documentation will be strengthened.
Another measure for the realization of the 'research orientation' task of the UP TS is to build and set up flexible learning environment where students can collaboratively work on solving and discussing problems. As described in details below, we have created a flexible space for fabrication (fab-space), together with a flexible space for group discussions and team working in the space of the 'Physik Grundpraktikum'.

Students- and skills-orientation: As we have stated above 'one of the expected results is skill building for students similar to those of real scientists. Many of those skills are important not only for a future research career, but are transferable to many other professions. Examples of those skills are problem solving, critical thinking, creativity, being confident while dealing with uncertainty, and persistency'. In addition, the soft skills often needed in scientific research such as teamwork, communication and documentation will be critical for the success of the students' team. The grading of the lab will occur based on the acquisition of those skills. We have prepared *(self-) assessment rubrics* for students, that we and the students can use as a self-assessment or peer-review tool (for students) and transparent grading (for us).
In line with the task 'Studierendenorientierung', in this project students will receive free space to determine how the project will develop, thereby teaching will become student-centered.

Digitalisation: Students will need to deal with programming for part of this project as well as with databases for scientific literature or spectral data. This in turn will strengthen their competence in digital media needed for research purposes.

4. Wie haben Sie Ihre Projektziele umgesetzt? Was wurde im Einzelnen gemacht? Bitte benennen Sie förderliche Aspekte und ggf. Hürden.
Bitte beschreiben Sie anschaulich, welche Methoden, Konzepte oder Szenarien Sie angewendet haben.

So far, we have realized the following steps:

Set up of the instrumentation: We purchased instrumentation and materials for the project: 3D printer, printing materials, CNC machine, PCs to soldering stations, optics, CCD cameras and high-resolution line cameras. We tried different CAD programs to use for the designing part of the project and identified the best for our teaching goals. We have set up the instrumentation and done all the required testing.

Modification of the lab environment: One essential part of our project was strengthening team work skills. For facilitating this aspect, we decided to modify our existing lab space.
We have worked on modifying our lab space to allow an open environment for fabrication and group discussions, like a fab-space. The old lab space had rows of benches with lab equipment on top. We have removed part of this ensemble, and substituted it by sets of small rolling tables that can be positioned in different settings depending on how many students of the groups participating in discussions and work processes. The tables are close to the soldering stations, 3D printer and CNC, allowing to integrate discussions, fabrication facilities, benches and test equipment. We installed large whiteboards for facilitating group discussions. We also provided a smartboard with pens for being able to record groups discussions, send the discussions sketches directly per email to the students and have access to the internet in a large format.

Preparation of the material for using the instrumentation: We have collected data sheets for the instrumentation and generated lab manuals to make them available for students.
We have carefully discussed the safety aspects of the project and prepared safety instruction guides for the students for using the instrumentations. We have also prepared personal protection equipment for the students to use during the project (for example safety goggles, gloves).

Preparation of the material for students: We have researched and identified the literature for students. In particular, this collection consists not only of books, but also in scientific papers about building spectrometers. This way, we can train students already in the bachelor phase to study literature in a scientific article format.
We have also prepared a document that guides students in this new format and explains all the new aspects that did not occur in the normal lab setting they have experienced so far in their studies.

Preparation of the Rubrics:
We have identified four major skill areas to be achieved, which are used for students grading. Those skills areas are: **Design, Modeling, Technical-Skills, Communication.**
We have defined each of those skills with a description of specific sub-skills and have explained their weight in the final grade. Students can then use those rubrics and skills lists as a reference during their work.

Development of students evaluation tools: we have planned and worked on material on how to evaluate students' success during the process. We decided to use the GE-Class, an online survey that we already use in our lab classes (takes about 8min to do the pre-test and 11 min to do the post-test). The GE-Class is a research-based assessment to test students' beliefs about the nature and importance of experimental physics, as well as their confidence and attitudes when doing physics experiments. The GE-CLASS is made of 30 statement-paired- items asking for students' personal

view about different aspect of experimentation. Students have to answer the same question from an expert perspective.
At the end of the course, the GE-CLASS assesses students' reflections on their course's expectations for earning a good grade. This last information is useful for assessing how our grade attitude is in accordance with our learning goals.

We have also prepared an evaluation 'Fragenbogen' to asses students personal evaluation of the project. Examples of questions are - Wo seht ihr Unterschiede zu vorherigen Versuchen im Grundpraktikum? - Welche Vorteile seht ihr in diesem neuen Konzept? - Welche Nachteile seht ihr in diesem neuen Konzept? - Habt ihr das Gefühl, neue Fähigkeiten im wissenschaftlichen Arbeiten erworben zu haben?

To study the success of the project in detail, we had also planned to conduct observations of students performance within a master thesis. This would have been based on an observation protocol that we had prepared and which focused on research skills and working attitudes. We had planned also to conduct students' interviews to address better students point of view about their experience in the project. At this point in time, we had to devote the master thesis to a different topic.

5. Welche zusätzliche Unterstützung wäre für zukünftige, ähnliche Projekte hilfreich?
Bitte benennen Sie Rahmenbedingungen, Ausstattungsmittel, Beratungsangebote oder Dienstleistungen, die dabei helfen würden, Projekte wie Ihres noch besser umzusetzen.

The process for acquisition of the instrumentation took a long time!
However, the support given by the ZfQ was really very good.

6. Wie sind die Studierenden mit den (neuen) Methoden, Konzepten oder Szenarien umgegangen?
Bitte schätzen Sie ein, wie der "studentische Blick" auf Ihr Projekt ausgefallen ist. Wurden Neuerungen angenommen oder gab es bemerkenswerte Rückmeldungen?

The evaluation of the project will be performed when we will be able conduct the project with students.

7. Fazit und Ausblick: Welchen Stellenwert hat das Projekt für Ihre zukünftige Lehre bzw. für die Lehre in Ihrem oder in anderen Bereichen?
Sollen Teile oder das gesamte Vorgehen Ihres Konzeptes dauerhaft in die Lehre eingehen? Handelte es sich um eine pilothafte Erprobung? Welche Gründe sprechen für oder gegen eine Verstetigung?

We want to offer the project in for many years to come. In fact, our goal is to integrate part of this experience into the normal weekly lab class. We had an ongoing master project with the aim of evaluating this project and develop an equivalent short version for the lab class in the semester. The master thesis had to be modified due to impossibility to realize the project in the near future.

II. Fragen zur Kategorisierung von Lehrprojekten

Bitte helfen Sie uns bei der Kategorisierung Ihres Projekts und setzen ein Kreuz bei den zutreffenden Punkten.
Eine Mehrfachauswahl ist möglich.

1. Einbezogene(s) Lehrveranstaltungsformat(e)

„X" an zutreffender Stelle setzen	
	Seminar
	Vorlesung

	Übung
	Exkursion, Studienreise
X	kleine Gruppen (1-20)
	mittlere Gruppen (21-49)
	große Gruppen (>50)
	sehr große Gruppen (>100)
	studentisches Projekt
Sonstiges/Anderes (bitte nennen):	Praktikum

2. Spezielle Lehrmethodik, spezielles Lehrarrangement

„X“ an zutreffender Stelle setzen	
	Projektmethode, Projektseminar
X	forschendes Lernen (bspw. Forschungsseminare, Problem Based Learning)
	interdisziplinäres Co-Teaching
	Co-Teaching
	Simulation, Planspiel
	Inverted Classroom Model, “Flipped Classroom”
Kooperation mit externem Partner (bspw. Service-Learning), nämlich (bitte nennen):	_____
Sonstiges/Anderes (bitte nennen):	_____

3. Neue Lehrinhalte

(Bitte in Stichpunkten beschreiben)
How to build a scientific apparatus
_____
_____

4. Gestaltungsebene(n)

„X“ an zutreffender Stelle setzen	
X	Lehrveranstaltung(en)
	Modul(e)
	Studiengang
	Studiengangsübergreifende(s) Angebot(e)
	Internationale(r) Kurs(e) (bspw. Online-International-Learning)
Sonstiges/Anderes (bitte nennen):	_____

5. E-Learning, Medieneinsatz

„X“ an zutreffender Stelle setzen	
X	Anreicherung mit Online-Angebot (bspw. begleitende Materialien)
	Integration (Blended Learning)
	Integration mit Ersatz von Präsenzveranstaltungen
	Virtuelle Lehre (bspw. MOOC)
	Einsatz von Video
	Virtuelle Realität, Augmented Reality
	360-Grad-Bilder

X	E-Assessment, elektronische Prüfungen
Sonstiges/Anderes (bitte nennen):	Programmierung, Benutzung von CAD Programme, 3D Druck Programme, Benutzung von Online share Tex Programme

6. Schwerpunkt auf folgende Zielgruppe(n)

„X“ an zutreffender Stelle setzen	
X	Studierende, allgemein
	nur BA-Studierende
X	nur MA-Studierende
	Lehramtsstudierende
	ausländische Studierende
	Studienanfänger*innen
	Berufstätige (bspw. Wissenschaftliche Weiterbildung)
	offenes Angebot (bspw. MOOC)
Sonstiges/Anderes (bitte nennen):	_____

7. Bezug zum Leitbild Lehre

7.1 Bezug zu den Themen des Leitbilds Lehre

„X“ an zutreffender Stelle setzen	
X	Forschungsorientierung
	Tätigkeitsfeldbezug und Persönlichkeitsbildung
	Interdisziplinäre und fachübergreifende Lehre
	Zielgruppenspezifische Lehre
X	Studierenden- und Kompetenzorientierung

7.2 Bezug zu den Querschnittsthemen des Leitbilds Lehre

„X“ an zutreffender Stelle setzen	
	Weiterbildung/Qualifizierung für Lehrende
X	Digitalisierung
	Heterogenität
	Internationalisierung
	Lehramt
	Kommunikation/Vernetzung (u. a. Aufbau einer Best Practice Datenbank)
	Qualitätsverständnis, Qualitätspolitik und Qualitätskultur

8. Bitte vergeben Sie Schlagwörter, die das Projekt weitergehend spezifizieren (bspw. "Hackathon", "Blockseminar")

Bitte freie Schlagwörter nennen
Praktikum
_____
_____
_____
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