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Evaluation of smartphone-based undergraduate research projects in introductory university physics

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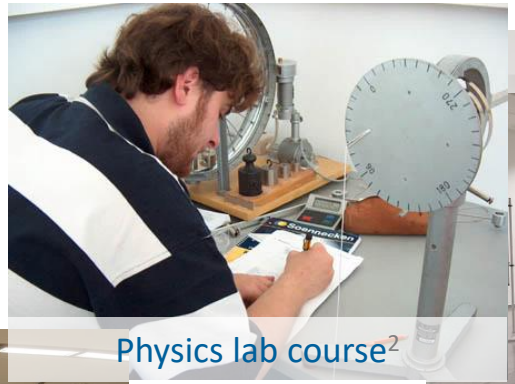
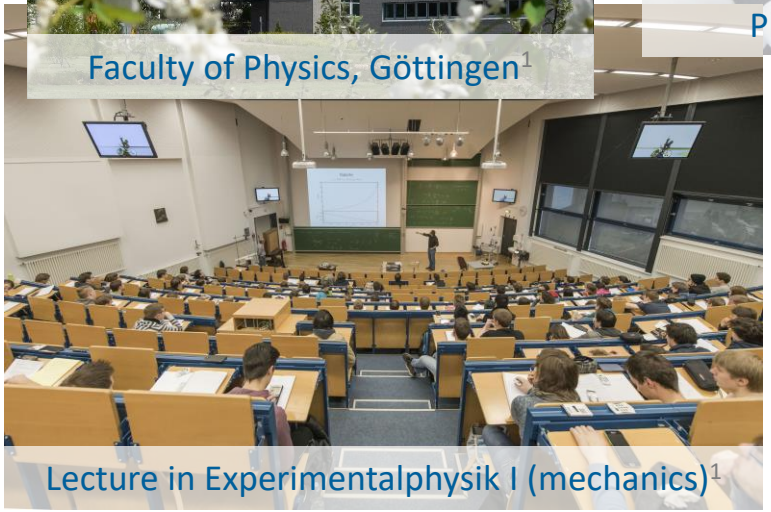
Faculty of Physics, Göttingen[1]



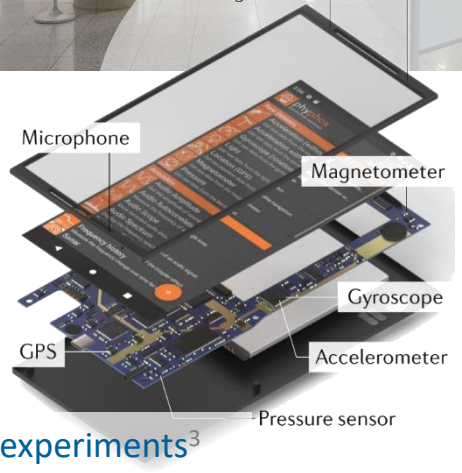
Physics lab course[2]

Group project work with poster session



Lecture in Experimentalphysik I (mechanics)[1]

Evaluation of smartphone-based undergraduate research projects in an introductory university physics



Smartphone experiments[3]

[1] https://goepix.uni-goettingen.de/collection/2aaa145d-d59a-43e3-9d72-e77623f56ea6; [2] http://www.praktikum.physik.uni-goettingen.de/allgemeines/bilder/AP_06/images/HPIM2310.jpg; [3] https://doi.org/10.1038/s41578-020-0184-2

Open experimenting with smartphones can improve physics teaching

Traditional strongly-guided experimental tasks are rather ineffective[1]

High potential of **open lab work**[2]

Especially **undergraduate research projects** (URPs),[3] e.g., to foster higher-order thinking skills (HOTs) like autonomy or curiosity[4]

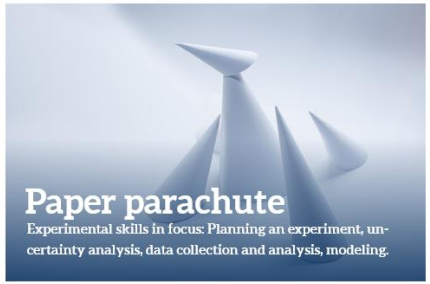
Positive effects of **experimenting with smartphones**, e.g., on motivation[5] & conceptual understanding[6]

Prior work on their implementation in university teaching[7] but not as UPRs

Smartphone-based URPs to foster students' affections (e.g., curiosity, interest) **& self-regulated, inquiry-based learning**

[1] (Holmes et al., 2017; Teichmann et al., 2022; Rehfeldt, 2017; Haller, 1999); [2] (Etkina, 2015; Holmes & Wieman, 2018); [3] (Oliver et al., 2023; Ruiz-Primo et al., 2011; Russell et al., 2007); [4] (Mieg et al., 2022; Murtonen, & Balloo, 2019; Walsh et al., 2019); [5] (Hochberg, 2016); [6] (Becker et al., 2020); [7] (Staacks et al., 2022; Hütz et al., 2017, 2019; Kaps et al., 2022; Klein, 2016)

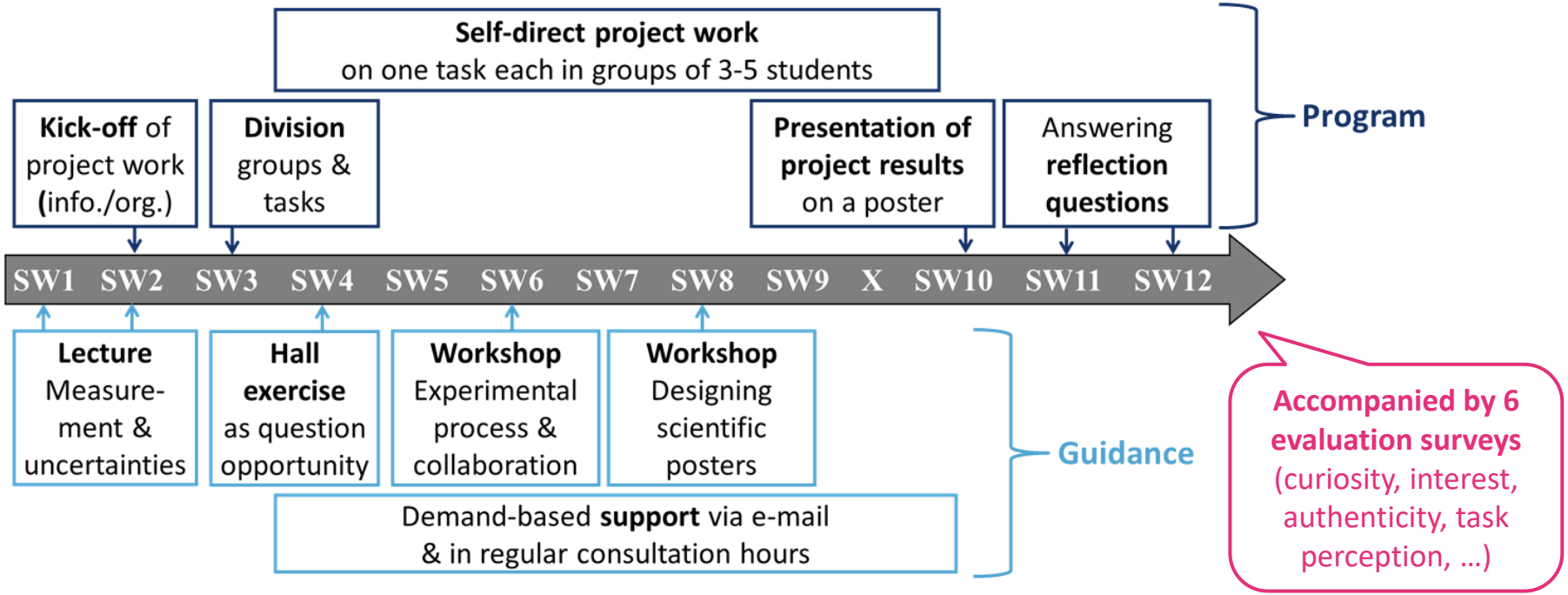
Six open experimental tasks for URPs were developed



"**Develop an experiment in which you investigate the frictional effects** that occur when the door slams shut. To do this, **use** the sensors of **your smartphone**. Then, experimentally **answer** the question of **which friction model describes the slamming door most precisely** […]. Also, **take uncertainties** of measurement **into consideration**."

(Lahme et al., 2023b)

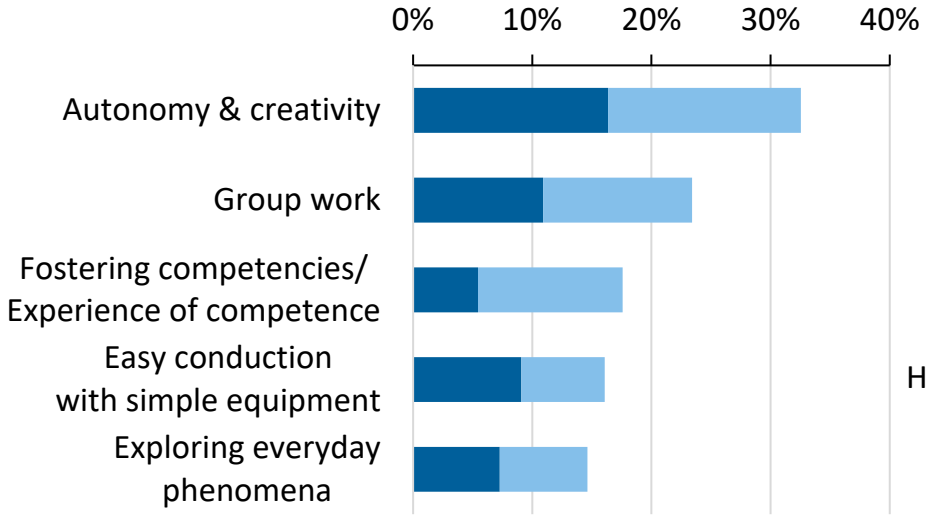
The tasks were implemented with guidance over the course of a semester



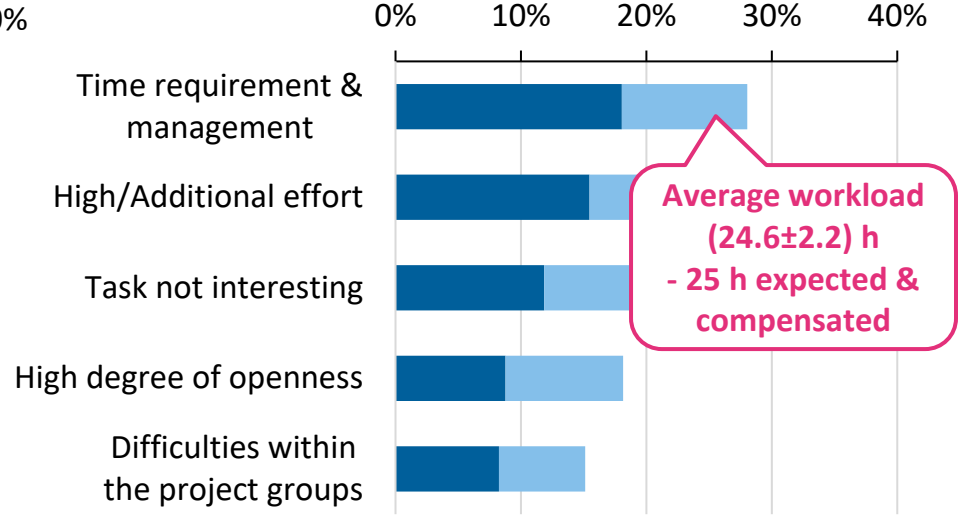
(Lahme et al., 2023b)

Open-text field responses reveal what students (dis-)liked about the URPs

Top 5 what the students liked

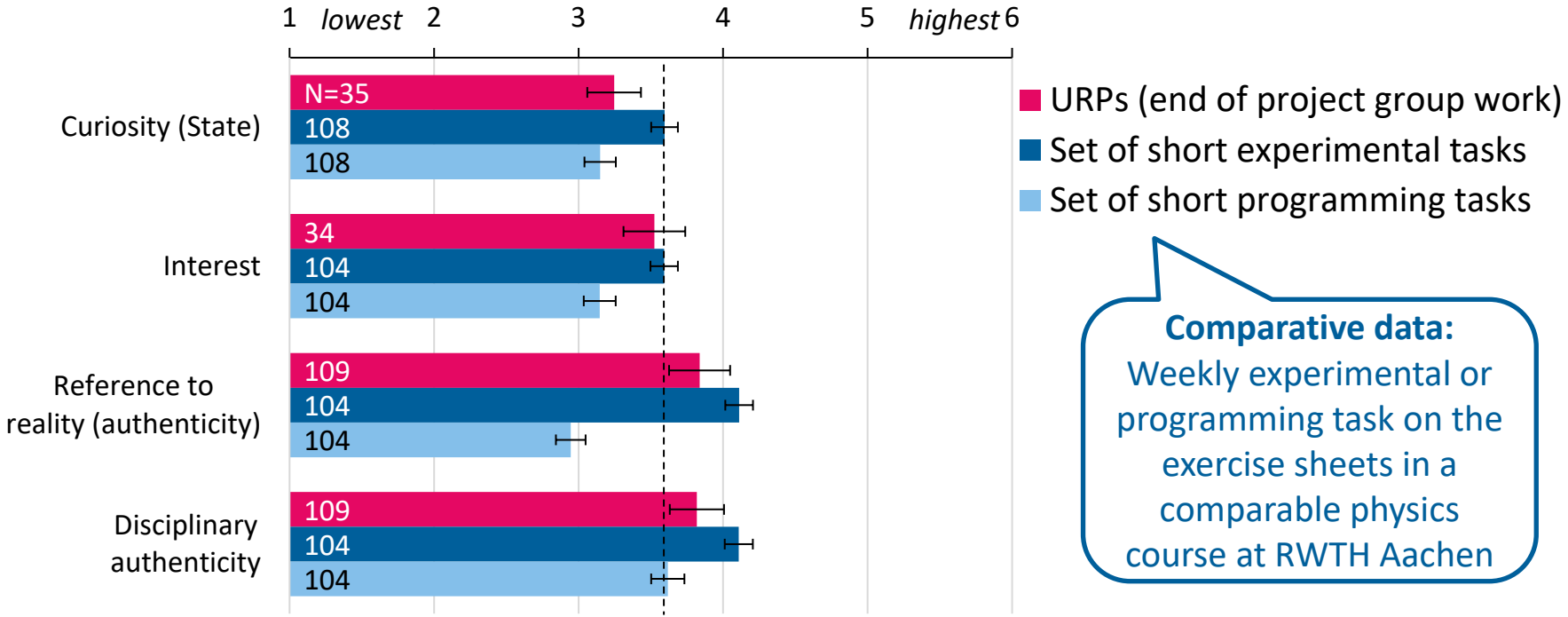


Top 5 what the students disliked



Percentage of codings per category in the responses to the … **Questionnaires** **Reflection question**

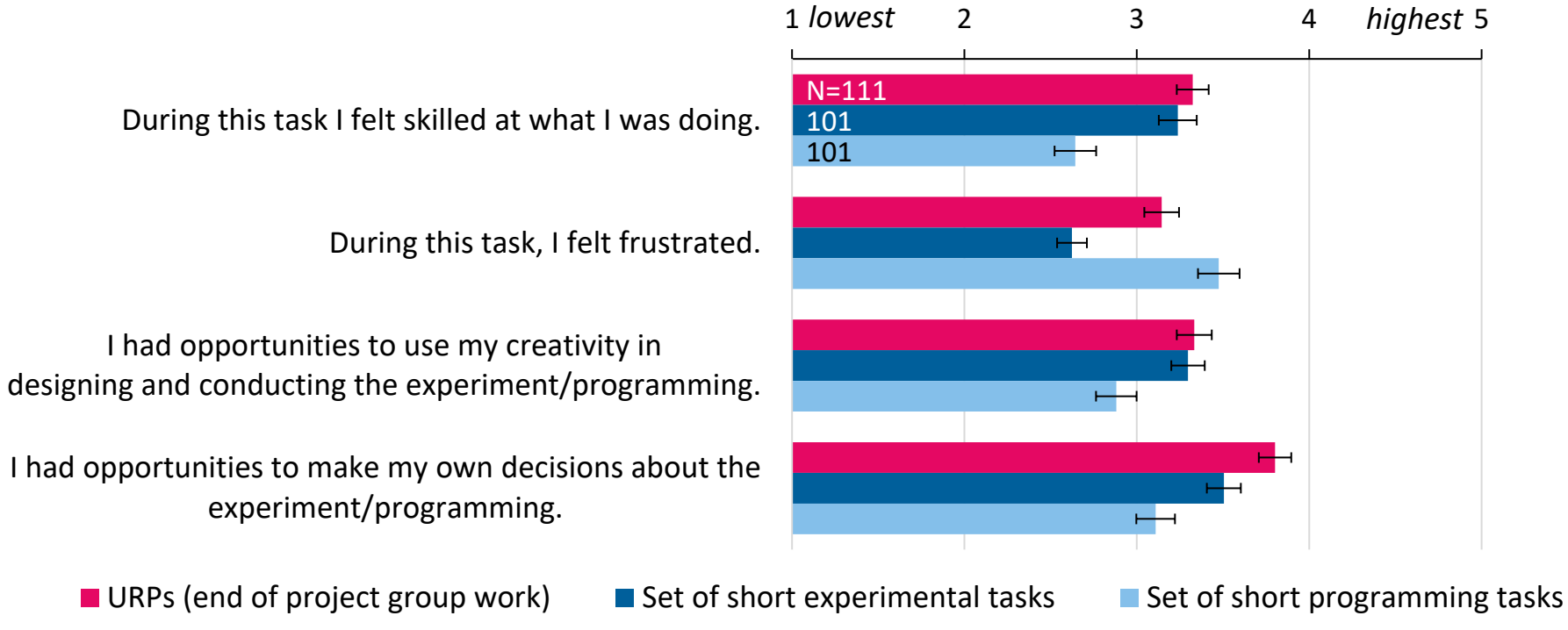
URPs elicit a similar affective response as short experimental tasks



Comparative data:
Weekly experimental or programming task on the exercise sheets in a comparable physics course at RWTH Aachen

(Items: Klein, 2016)

URPs can be frustrating, yet they also foster experience of competence & autonomy



(Items: Lahme, 2023a)

Summary

- **Proof of concept:** Smartphone-based URPs can be implemented in a first-year physics course
- **Impression of potentials and challenges of this approach**
- **URPs produce similar results on an affective level as short experimental tasks**, so the high level of openness was not detrimental

Outlook

- Ongoing data collection in Aachen will allow comparison with regular problem-solving tasks
- Further data analysis & comparison with reference data[1] will provide deeper insights in the innovation of introductory physics with smartphone-experiments

URP task documents as Open Educational Resources (OER) *in German & English*
https://doi.org/10.57961/49zr-w490

Website of the presented project *in German*
https://www.uni-goettingen.de/de/657593.html

Website of the foregoing Erasmus+ **DigiPhysLab-project** *in English*
https://jyu.fi/digiphyslab

[1] (e.g., Kaps & Stallmach, 2022; Klein, 2016; Ruiz-Primo et al., 2011)

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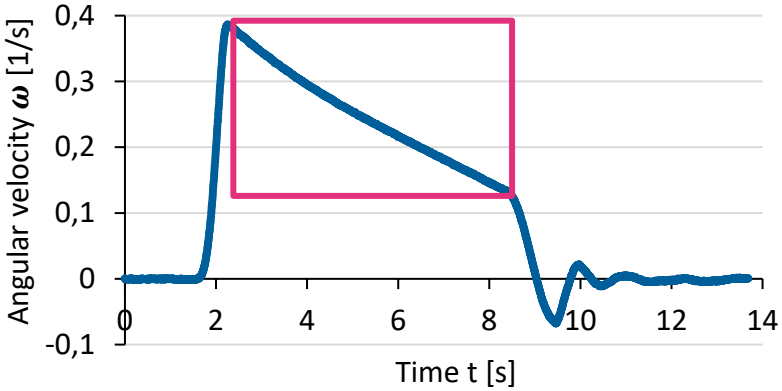
Appendix

Deeper insight in the Slamming Door task

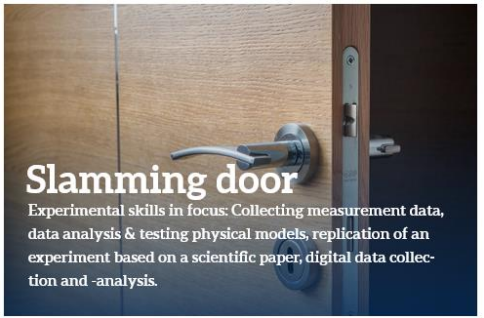
The task: Develop an experiment in which you investigate the frictional effects that occur when the door slams shut. To do this, **use** the sensors of **your smartphone**. Then, experimentally **answer** the question of **which friction model describes the slamming door most precisely** […]. Also, **take uncertainties** of measurement **into consideration**.

+ guiding questions, literature references, …



Fitting the data with models combining dry (D $\sim\omega^0$), Stokes (S $\sim\omega^1$) & Newtonian friction (N$\sim\omega^2$) based on the differential equation

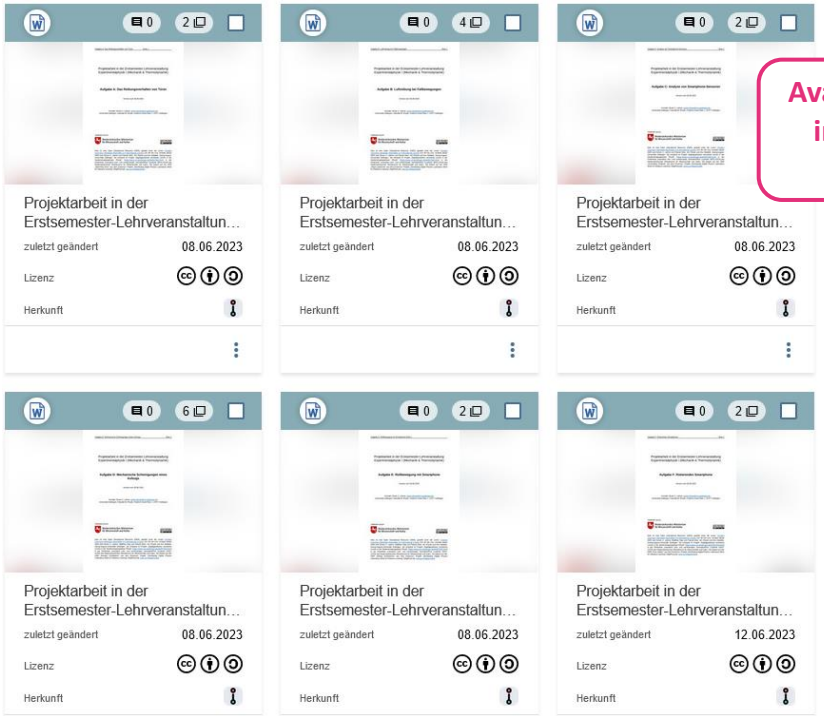
$$a + b\omega + c\omega^2 = -I\dot{\omega}$$



(Klein et. al., 2017; Lahme et al., 2022a)

Outline of the task documents

Structural elements in the instructions
1 Motivation and overview
2 Your task
3 These guiding questions might be of use while working on the task
4 What you should learn in this task
5 What should be on your poster
6 A few more tips for implementation
7 Additional questions for more in-depth analysis
8 References
9 Additional supportive materials
10 Recommended schedule
11 If you need support during the project



Available as OER in German & English

https://doi.org/10.57961/49zr-w490

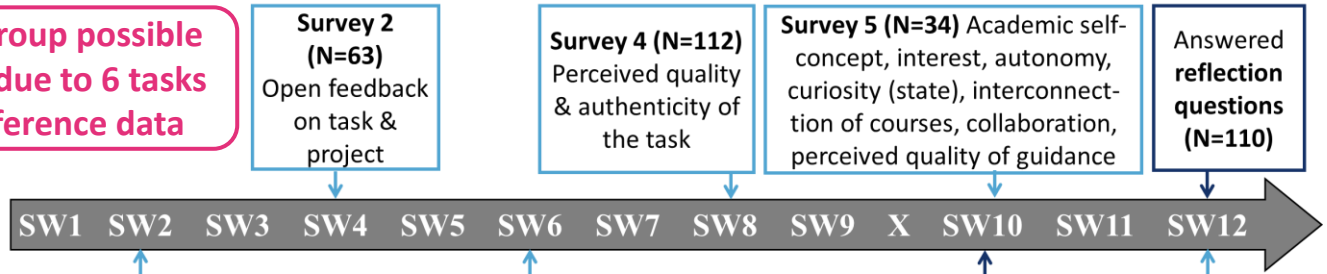
Project Evaluation – Overview of measured variables

Evaluation of the tasks and the project implementation itself

→ Potential for improvement of tasks and program for possible future repeats

→ Proof of concept / Feasibility of smartphone-based undergraduate research in 1st semester

No control group possible → variation due to 6 tasks & use of reference data



Survey 1 (N=125) Prior experience, view on experimental physics, sense of belonging (physics community), curiosity (trait), academic self-concept, attitude toward digital technologies

Survey 2 (N=63) Open feedback on task & project

Survey 3 (N=65) Sense of belonging (university), curiosity (state), interest, interconnection of courses, collaboration, open feedback on task & project

Survey 4 (N=112) Perceived quality & authenticity of the task

Scientific poster (N=39) per group

Survey 5 (N=34) Academic self-concept, interest, autonomy, curiosity (state), interconnection of courses, collaboration, perceived quality of guidance

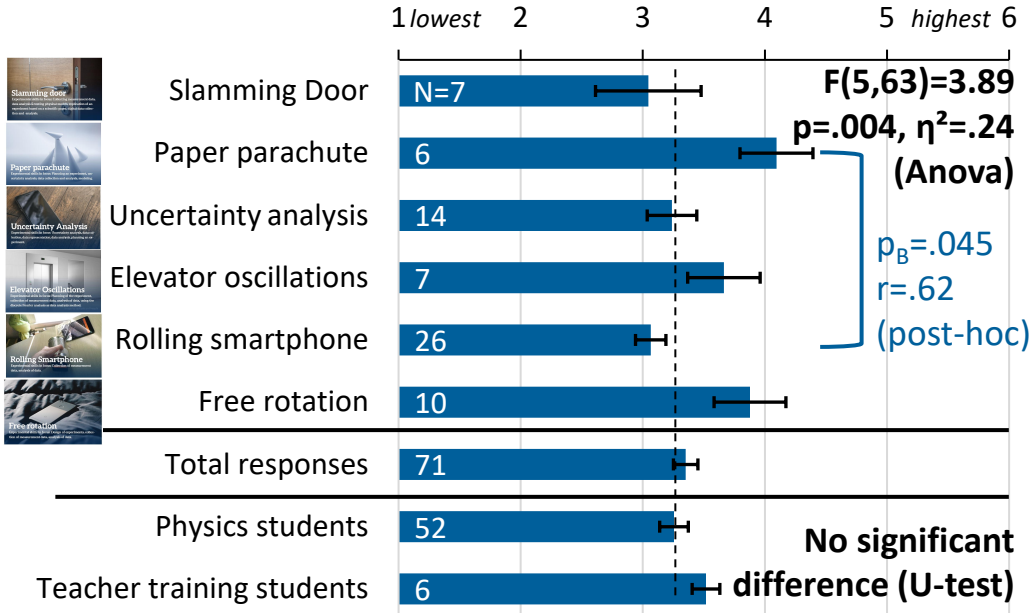
Survey 6 (N=19) View on experimental physics, attitude toward digital technologies, sense of belonging (physics community & university)

Answered **reflection questions (N=110)**

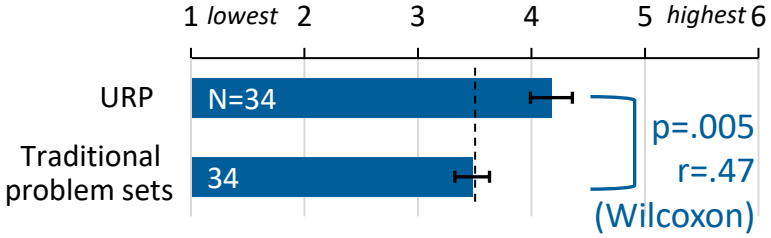
(Dickhäuser et al., 2002; Klein, 2016; Lahme et al., 2023a, 2023b; Rauschenbach et al., 2018; Rehfeldt, 2017; Schmechting et al., 2020; Teichmann et al., 2022)

Further insights in the project evaluation

Interest caused by the URPs



Perceived autonomy



Correlation Interest - Autonomy URP: r(32)=.47, p=.005 → moderate

(Items: Klein, 2016)