

Computer-assisted data acquisition in Basic Physics Laboratory Courses

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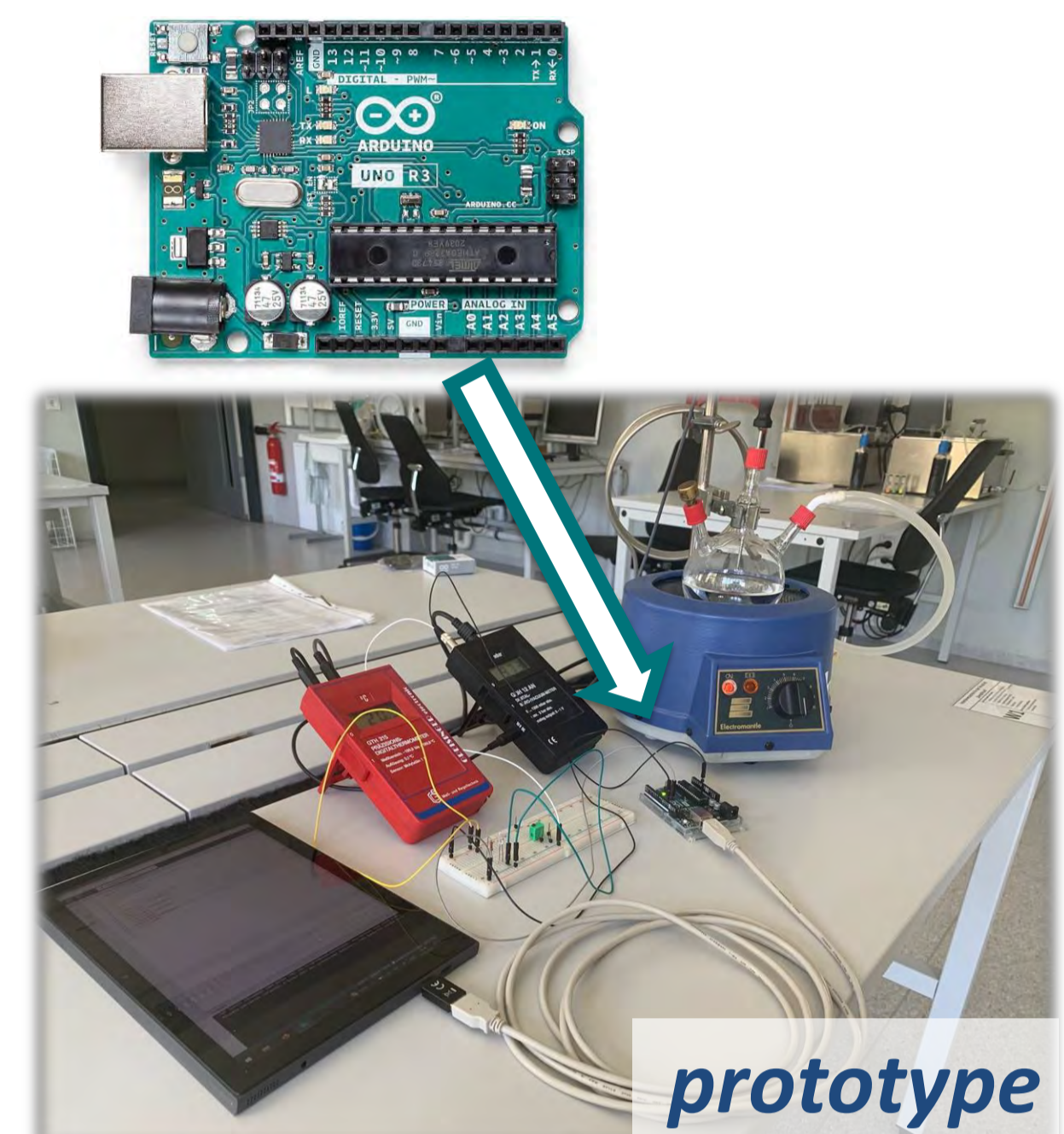
While testing new concepts in the basic physics lab course at the TU Ilmenau, one focus has been on computer-assisted data acquisition in selected experiments. There, we opted for a similar approach as reported by Haugen and Moore [1]: Students perform a physical experiment using one or more sensors and an *Arduino* microcontroller.

[1] Haugen, A.J., Moore, N.T.: A Model for Including Arduino Microcontroller Programming in the Introductory Physics Lab. Eprint arXiv: 1407.7613 (2014)

This approach to upgrade long existing physical experiments by microcontrollers is appreciated by the students, which has been evaluated through comprehensive questionnaires. They show a higher motivation throughout the whole experiment and judge the competence of microcontroller and data handling very valuable for further practical projects. We couldn't observe any negative impact on the main learning goals of the lab course.

Basic Idea

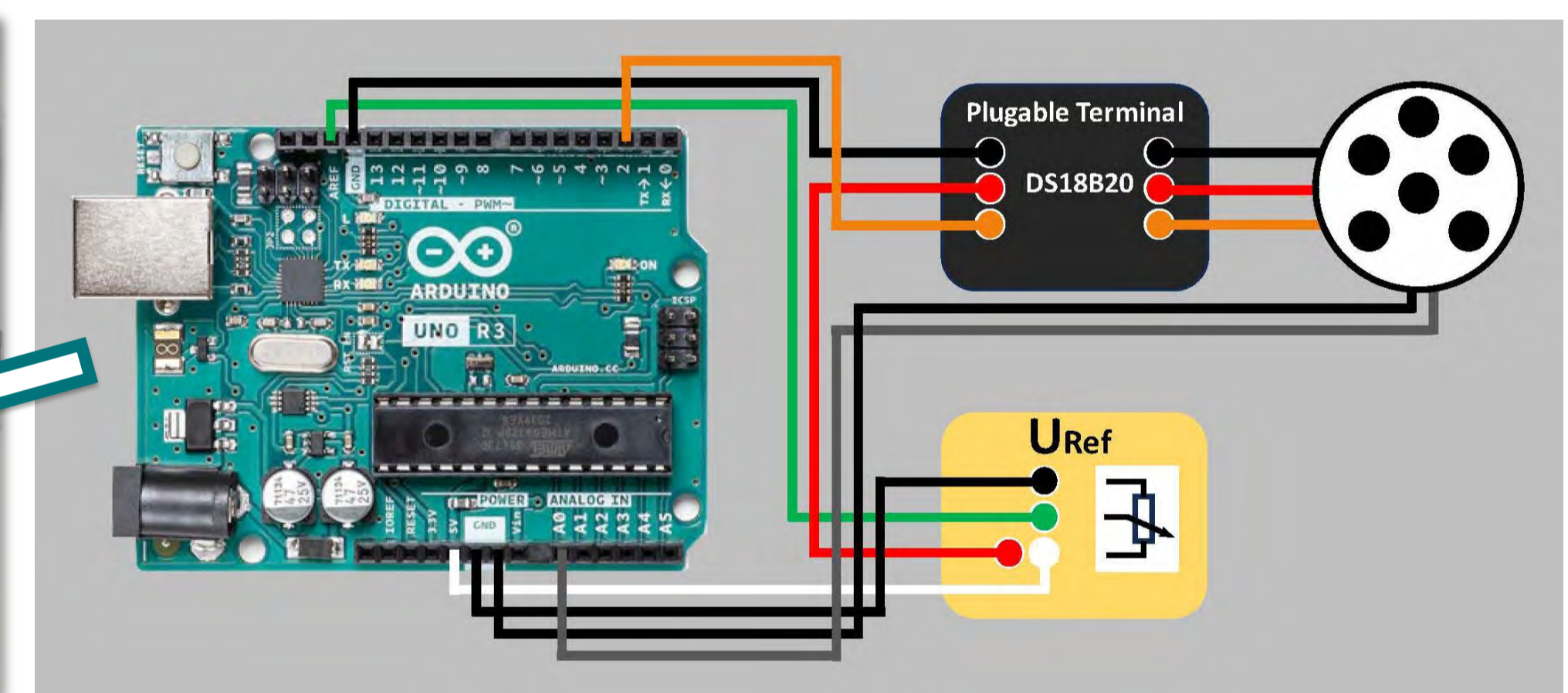
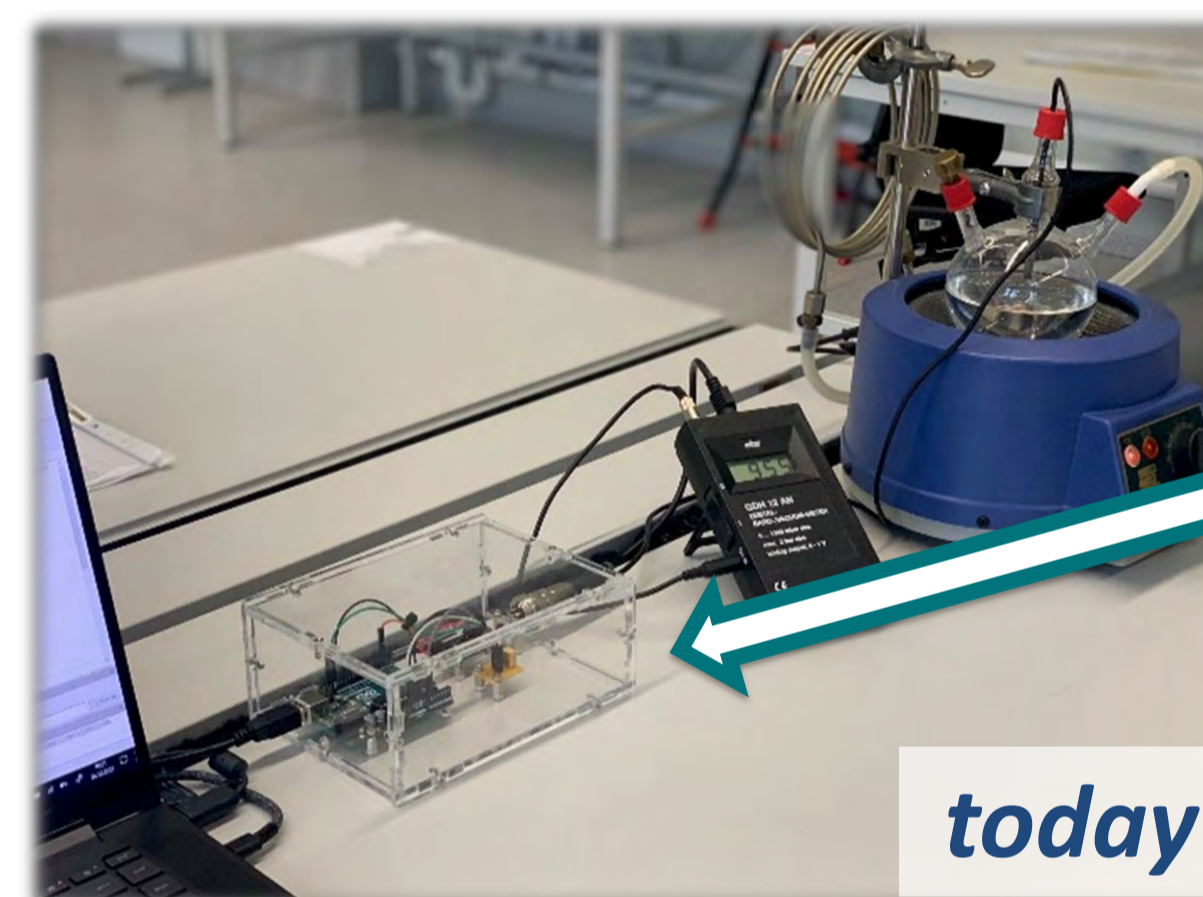
- essential learning goals of the physics lab course: independent realization of an experiment, scientific analysis of the data and clear presentation of experiment and its results in a report
- important requirement for today's engineering graduates: to master the communication of computers with measuring devices or sensors and the associated computer-aided data analysis
- therefore, addition of a secondary learning goal: students perform a physical experiment using one or more sensors and a microcontroller
 - use of *Arduino Uno* physical computing platform due to its broad spectrum of applications
 - due to limited time during the lab course, programs aren't implemented from scratch, but students get bricks of the final source code
 - for some experiments wiring still needs to be made between microcontroller and sensors
 - after completion of data acquisition, students need to deal with formatting of the collected data and to make it readable by the analysis software
- motivated by positive evaluation *Arduino*-supported experiments are now an integral part of the physics lab course for all degree programs
- experiments with increasing complexity of *Arduino* use are performed consecutively



Practical implementation for the experiment "Vapor pressure of water"

experimental procedure:

- water in an open vessel is heated up until boiling point, then the vessel is closed, and the heat supply is stopped
- sensors detect pressure p and temperature T in the vessel during cooling
- **so far:** students note readings of measuring devices by hand and transfer the respective values to the analysis software → time consuming and error-prone procedure
- **now:** temporal evolution of p , T measured by *Arduino*



student preparation:

- previous knowledge in microcontroller handling very heterogeneous
- document containing basic facts about *Arduino Uno* (hardware, IDE software, programming)
- additional handout with experiment-specific information (wiring of *Arduino*, parameters of the used sensors, necessary libraries,...) and main parts of the source code

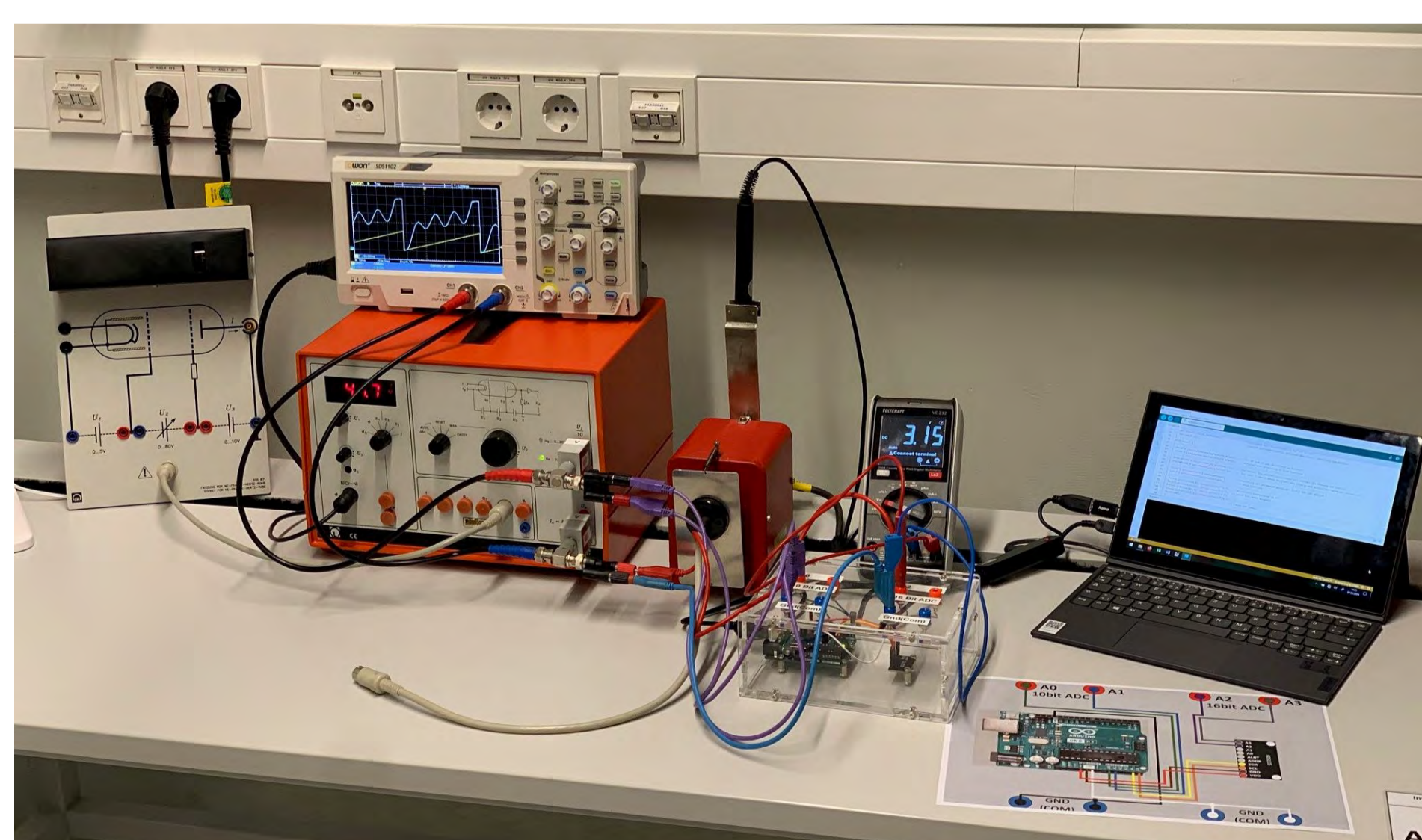
evaluation by students:

- although the use of *Arduino* for the experiment is voluntary, so far, all students opted for it
- getting in contact with microcontroller programming and subsequent digital data handling are judged as very valuable for further practical projects
- positive side effect: *Arduino* conducts time consuming measurement "on his own" and students can spend their time on other experiment parts or data analysis

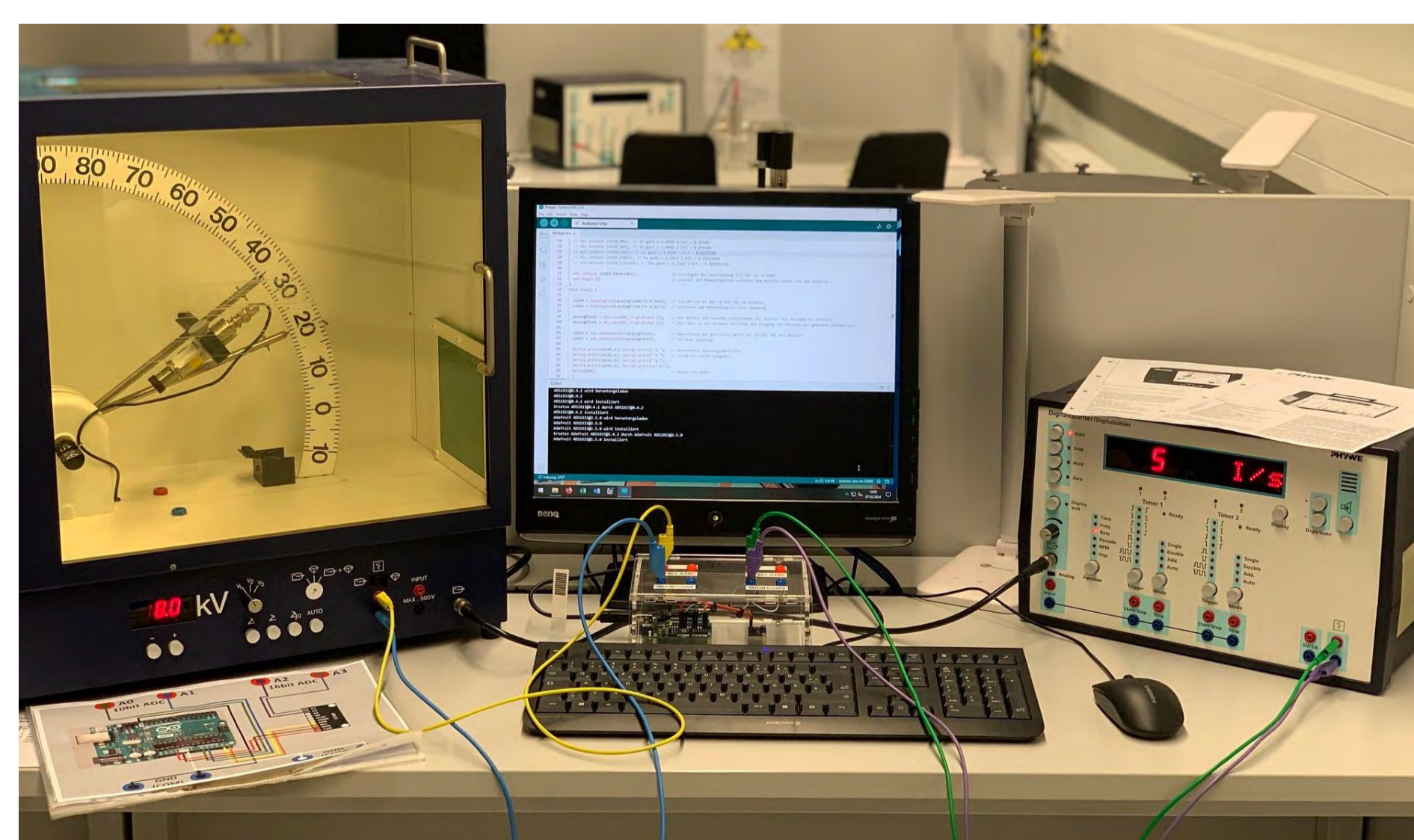
observation by tutors:

- students show a higher motivation throughout the whole experiment and even beyond
- main learning goals are achieved as before but clear additional benefit by gaining basic knowledge about microcontroller handling

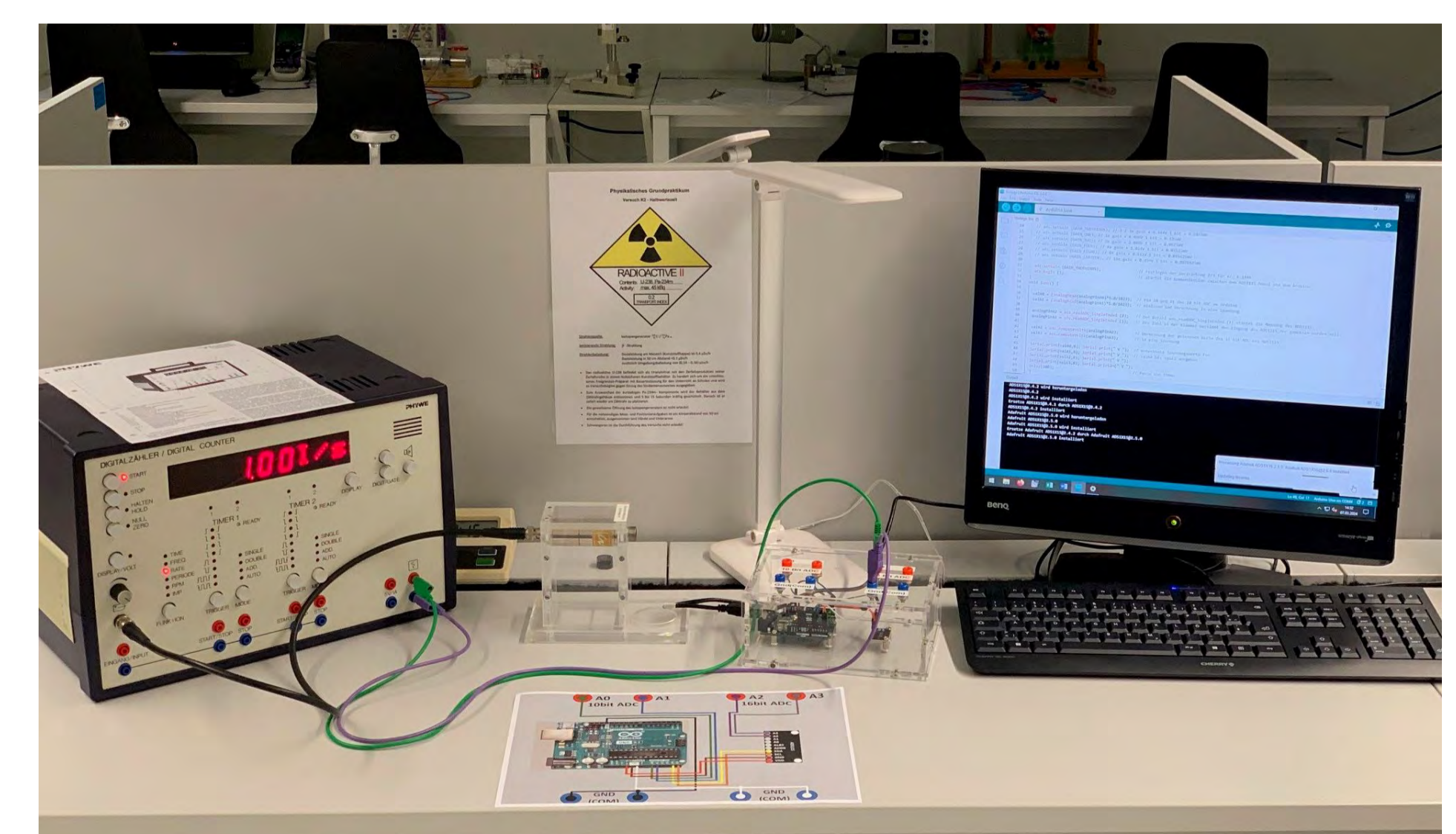
Arduino application in further experiments



Franck-Hertz experiment



X-ray spectra



radioactive half-life

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