



From face-to-face internships to blended learning formats

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Abstract

This article documents the iterative development and evaluation of the internship in the Measurement and Automation Technology module in the Mechanical Engineering and Process and Natural Materials Engineering degree programs at the Faculty of Mechanical Engineering at Dresden University of Technology.

In response to the coronavirus pandemic, the traditional laboratory practical course was converted via the intermediate stage Praktika@home into a blended learning format, the core element of which is a mobile experiment kit based on Arduino. Accompanying evaluations have shown that the switch to a blended learning concept has significantly increased student engagement. However, ongoing analysis also revealed challenges that needed to be addressed for the successful development of the teaching/learning concept. In conclusion, it has become clear that systematic, evaluative support is essential for the development of new teaching/learning concepts. Future development goals include the integration of a digital twin for multimedia processing and the dissemination of the format to other engineering disciplines such as electrical engineering.

Dieser Beitrag dokumentiert die iterative Entwicklung und Evaluierung des Praktikums im Modul Mess- und Automatisierungstechnik in den Studiengängen Maschinenbau sowie Verfahrens- und Naturstofftechnik der Fakultät Maschinenwesen der Technischen Universität Dresden.

Als Reaktion auf die Corona-Pandemie wurde das klassische Laborpraktikum über die Zwischenstufe Praktika@home in ein Blended Learning-Format überführt, dessen Kernelement ein mobiler Experimentierkoffer auf Arduino-Basis bildet. Im Rahmen von begleitenden Evaluierungen hat sich gezeigt, dass der Wechsel hin zu einem Blended Learning-Konzept das Engagement der Studierenden signifikant steigern konnte. Allerdings zeigte die fortlaufende Analyse auch Herausforderungen, deren Behandlung für eine erfolgreiche Entwicklung des Lehr-/Lernkonzepts wichtig war. Im Fazit hat sich gezeigt, dass eine systematische, evaluierende Begleitung für die Entwicklung neuer Lehr-/Lernkonzepte zwingend erforderlich ist. Zukünftige Entwicklungsziele umfassen die Integration eines digitalen Zwillings zur multimedialen Aufbereitung sowie die Dissemination des Formats auf andere ingenieurwissenschaftliche Disziplinen wie die Elektrotechnik.

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1. Introduction

The Measurement and Automation Technology (MAT) course is a two-semester module that starts in the winter semester. The module consists of two semester hours per week (SWS) of lectures, one SWS of computer exercises, and one SWS of practical training and is part of the mechanical engineering and process and natural materials engineering programs at the Faculty of Mechanical Engineering at TU Dresden. It is attended by approximately 350 students annually (as of the 2025/26 winter semester).

A central element of this course and the subject of this article is the practical training, which is designed to familiarize students in their 5th and 6th semesters with experimental work in measurement technology. They need this experience in their practical training, which follows in the 7th semester in the form of a specialized internship.

In the classic design of the module, due to the large number of students, which amounted to up to 800 participants per semester in the 2010s, the internship was designed as an internship with large groups at prefabricated test benches, where students carried out and evaluated a series of experiments in a three-hour attendance phase (Fig. 1).

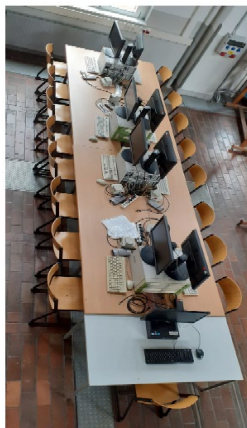


Figure1 : Typical arrangement of the classic classroom internship (here, measurement dynamics) for 16 participants and one supervisor before the pandemic phase

Such mass practicals have the major disadvantage that they do not encourage the active participation of the students themselves and

therefore have little learning effect. At the same time, changing such practicals when there are large numbers of students involves considerable risks, which usually means that the practicals are continued in their existing form, despite the known shortcomings.

When, at the beginning of the 2020 summer semester (SoSem), the established mass internships could no longer be carried out for hygiene reasons due to the coronavirus pandemic, a situation arose that forced changes to the internships (Chapter 2), as students had to complete the corresponding exams in order to continue their studies despite the pandemic restrictions. A major advantage in this situation was that the students had already been taught at the chair in the first part of the MAT course in the 2019/20 winter semester (WiSem). This meant that they could draw on material they had already learned to design initial experiments that they could carry out using resources available in their households. The term Praktika@home was introduced for the experiments at home.

Supervising the first Praktika@home via available chat services proved to be inefficient and extremely problematic. Despite these difficulties in supervision, the results of the first reports showed that the students had carried out and evaluated extensive investigations with a high level of commitment, often exceeding the required level.

As the restrictions on face-to-face teaching were only slowly lifted in the following semesters and the students were able to be introduced to practical work much more intensively in the internships that could be carried out at home than the mass internships of previous semesters had allowed, the concept was further developed (Chapter 2).

A key factor in this further development was the introduction of experiment kits based on Arduino microcontrollers, which allow experimental work with real measurement technology.

In the meantime, on-campus operations have been restored for almost 2.5 years, but the Praktika@home concept is being continued due to its success. The entire internship has now been completely converted to a blended learning format (combining the advantages of

on-campus study with the advantages of studying at home). The various stages of this development and its conception within the framework of an evaluation-based development concept will be presented below, with a particular focus on the evaluation analysis, which is discussed in detail in Chapter 3.

The outlook section will show how such a concept can be kept up to date through the use of modern technologies and what opportunities, but also difficulties, may arise when disseminating such concepts to other subjects (Chapter 4).

2. Development steps

Before the pandemic, MAT practicals were conducted as traditional laboratory practicals. Students prepared independently and, after a brief introduction, the experiment was carried out, evaluated, and recorded within a three-hour period.

The advantage lay in the use of high-quality equipment that enabled precise and reproducible measurements. The disadvantages were the very limited attendance time and the low learning effect with insufficient preparation, as motivation for self-study was often low. Another didactic problem was that the actual interconnection of the components, such as in the strain measurement (DM) experiment, was done via slots, which made it abstract and impossible to experience [1].

Phase 1 – from the laboratory to the home environment

The first phase was the immediate response to the contact restrictions imposed during the pandemic starting in the summer semester of 2020.

While the lecture could be held on YouTube and the exercise could be conducted online via Matrixchat, the practicals presented a greater hurdle [1].

In the face-to-face practical course, 16 students worked together in groups of two, which resulted in about 110 practical course units for a total of 600 students. Each of these was led by a tutor. Due to social distancing rules, only three to four participants were allowed in the practical training rooms at the same time in

the 2020 summer semester, which would have resulted in at least 450 practical training units in theory. This was impossible to organize in terms of space and personnel. Nevertheless, the practical training was and is essential for knowledge acquisition and practical experience. It was also not possible to cancel internships that were part of the curriculum, and postponing them to later semesters was unacceptable due to the unpredictability of further developments and the associated additional burden on students [1].

For this reason, a large part of the internships were digitized and adapted to the home environment—with the ulterior motive of preserving important practical work for the students. At the same time, strengthening the students' motivation to engage intensively with the content was an important aspect from the outset and remained significant in the subsequent phases.

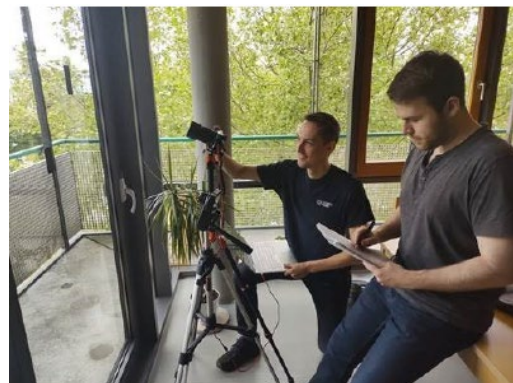


Figure 2 : Students in an empty student dormitory conducting the camera characterization experiment [1]

The three experiments that were regularly conducted in the summer semester are those on measurement dynamics (MD), control loops (CL), and programmable logic controllers (PLC). When transferring to the Praktika@home concept, care had to be taken to ensure that, in the case of software-supported experiments, every operating system was capable of implementing the content and that the materials for practical experiments were freely available in the home environment. The control loop experiment was therefore omitted in the first implementation phase due to the complexity of transferring it to the home environment. The

missing experiment was replaced by an experiment on digital image processing, in which a camera was characterized in terms of its resolution (Fig. 2). The camera of a cell phone, tablet, or laptop could be used for this purpose. In addition, a razor blade or, alternatively, a knife blade was required, i.e., objects that could be assumed to be accessible to at least one of the students.

Instead of an introduction by the tutor, there was an introductory video [V1-V4] for each experiment. The students had approximately three weeks to complete each experiment. Halfway through, they were able to ask questions and discuss problems via a TU Dresden Matrix chat room, with 60 students at a time. The resulting transcripts were also uploaded digitally to the OPAL teaching/learning platform.

There was 100% participation in the practical experiments. In addition, the students were well prepared for the consultation in the Matrix chat rooms and asked much targeted questions. Subsequently, the logs to be submitted contained far more content than was required [1].

However, the evaluation in Chapter 3 shows that the implementation of the consultations was associated with greater difficulties.

Phase 2 – Design and establishment of the Arduino case

Since the pandemic continued to have a massive impact on teaching even after the 2020 summer semester, the experiments for the subsequent 2020/21 winter semester also had to be planned without in-person attendance. At this point, the idea of establishing Praktika@home as a new teaching/learning model in the long term was already included in the planning, as the first pandemic semester had shown that students were unusually engaged with the internship content, which led to better learning outcomes [1].

For capacity reasons and due to serious delivery problems with electronic components caused by the blockade of the Suez Canal in March 2021, the experiment program had to be regularly adjusted and adapted to the avail-

ability of experiments until the 2022/23 academic year. An accompanying evaluation (Chapter 3) has supported this development process since 2022.

An overview of the development of the experiment compilation is shown in Table 1.

Table 1: Overview of the development of MAT internship experiments.

Semester	Experiment
Summer semester 20	MD DBV SPS
WiSem 20/21	DBV MD VPF
SoSem 21	MK RK SPS
WiSem 21/22	MD MK VPF
SoSem 22	DM RK SPS
WiSem 22/23	From here on, experiments as in WiSem 21/22 – face-to-face meetings
SoSem 23	
WiSem 23/24	Introduction of theme days

Key

The entire module spanning two semesters is highlighted in color.

- MD - Measurement dynamics
- DBV - Digital image processing
- PLC - Programmable Logic Controller
- MK - Measurement chain
- RK - Control loop
- DM – strain measurement
- Color change – one academic year/module each MAT

In the 2020/21 winter semester, due to the aforementioned lead times, the two experiments on digital image processing and measurement dynamics already established in the 2020 summer semester had to be used again, which meant that the corresponding lecture

content had to be shifted between the two semesters. In addition, there was an experiment on experimental design and error calculation (VPF), in which students were asked to set up a pendulum and use it to determine the acceleration due to gravity [1].

With funding from the TU Dresden's FOSTER (Funds for Student Research) program, the second phase of internship development was implemented with a view to the coming summer semester. The FOSTER program provides financial support for research projects carried out by students or initiated by teachers with the aim of introducing students to scientific research at an early stage, strengthening their interdisciplinarity, and thus promoting young scientists.

Building on the experiences of the first phase, a more didactically sustainable and scalable system was designed for implementing various experiments on a common hardware basis. At the heart of the experimental kit developed (Fig. 3) is the Arduino UNO microcontroller. The kit also contains various sensors and actuators [5]. This ensures that real-world experimentation can continue, and by working with the Arduino, students learn not only the actual learning objectives of the experiments, but also how to build electrical circuits and control and program those using computers [1].



Figure 3: Experiment kit with the Arduino, sensors, actuators, and cables (current contents)

In order to familiarize students with the Arduino, introductory experiments were devel-

oped and placed at the beginning of the practical experiments. Simple circuits are set up in which LED's serve as central components. Participants learn how to control them using the Arduino and how to program the lighting duration and frequency.

The following section focuses on the development of experiments on control loops and strain measurement in the 2022 summer semester as an example to show the effort involved in developing experiments that students can carry out at home with the materials provided.

Before the pandemic, the **control loop** experiment consisted of a plexiglass tube in which water was moved by a pump and the water level was determined by a pressure sensor (Fig. 4 l.). The development of the Praktika@home experiment involved considerable technical and methodological challenges. The first prototype consisted of a high-temperature tube and a hair dryer fan, which was used to move a Styrofoam ball. An ultrasonic sensor was used to detect its position. The target distance could be controlled with a potentiometer [5]. Holes in the tube caused pressure losses that counteracted the non-linear relationship between ball distance and motor power. The result is a linear relationship between motor power and ball height, which can be controlled with a PID controller. This corresponds to the learning objective of the original experiment with the water pump.



Figure 4: Original control loop experiment (submersible pump) (left) and components of the first prototype control loop for Praktika@Home (right) [5]

In the next step, the Styrofoam ball was moved using an Arduino controller with the aid of a PC fan with a suitable holder in a Plexiglas tube instead of a high-temperature tube (Fig. 4 r.). Distance measurement with an ultrasonic sensor, as in the prototype, was adopted and integrated into the Arduino controller. Except for the tube, the materials were included in the borrowed case. The Plexiglas tubes were distributed separately to the students present in Dresden. Alternatively, there was a DIY version for those who were unable to return to Dresden from their home countries due to travel restrictions, for example [5]. Here, too, outstanding student versions were created in DIY projects (Fig. 5).



Figure 5: Student-built control loop experiment [5]

In the 2021/22 winter semester, the experiments were redesigned so that previously developed experiments could be reused. In order to restore the original didactic concept of the lecture, an experiment for **strain measurement** was designed in parallel for the 2022 summer semester.

For implementation in the suitcases, bending beams were developed, each carrying five strain gauges (SG) that can be connected in different ways in Wheatstone bridge circuits (Fig. 6). This also allows students to experience the advantages of using bridge circuits for improving measurement signals and suppressing crosstalk.

Basic programs for the microcontroller were provided for all Arduino experiments in order

to keep programming requirements to a minimum.

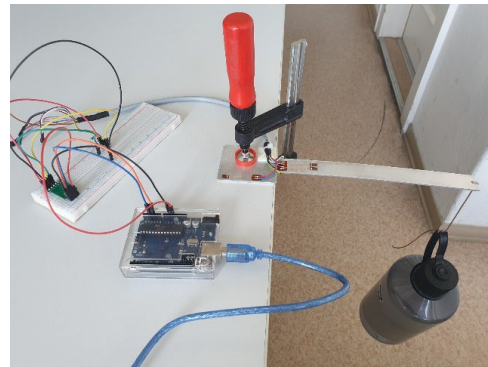


Figure 6: Overall setup of the strain measurement experiment for home use

In addition to the design, this phase included the logistical challenge of assembling, packaging, and securely distributing the cases, as well as organizing the return process.

The switch to the Praktika@home experiments resulted in significantly higher student engagement and a more positive perception of the practical course material, as described in detail in Chapter 3 on evaluation. Students used the time available at home to engage with the experimental content more intensively than usual [1].

One positive effect was the reduction in the amount of time and personnel required for on-site tutoring.

Phase 3 - Back to face-to-face learning

With the easing of contact restrictions, student counseling was moved back from the Matrix chat rooms to face-to-face sessions. As already mentioned, the didactic concept of the Praktika@home experiments with the suitcase remained unchanged, which meant that the challenge was to provide students with suitable teaching/learning formats for the consultations accompanying the practical training. A key aspect here was that, after two years of isolation, the students had to be motivated to attend face-to-face events again.

This development took place in several stages, which will not all be described in detail here. The end result is currently the concept of so-called theme days, where students not only

work on direct questions about the experiments, but also on lecture content on their own.

There are a total of three theme days per semester. Each theme day covers a practical training topic (MD, MK, VPF, DMS, RK, SPS) (see Table 1).



Figure 7: Students visualizing their group work on a pinboard

For each theme day, students are given various tasks to complete at home using the Arduino kit. A total of five task complexes are distributed around the respective practical training topic. Each of these five task complexes is worked on by four independent groups of two. On the attendance days, these four groups are brought together for discussion rounds. They compare their answers, visualize them on pinboards (Fig. 7), and present them to the whole group (Fig. 8). In this way, all students in the plenary session learn about all five task complexes. With this system, up to 40 students can participate in a theme day.



Figure 8: Students in group work; control loop experiment

In these face-to-face sessions, students acquire not only subject-specific skills but also interdisciplinary skills relating to exchange within a group and the visualization and presentation of results. The theme days thus integrate the so-called 21st century skills [9] directly into a subject-specific course.

In a second round of tasks, the discussion groups are assigned further tasks that build on the results achieved so far and specifically address potential problems in the internship. These tasks are completed and presented in the same way as in the first round (Fig. 9).



Figure 9: Face-to-face event Theme day

3. Evaluation

The drastic changes described above, from traditional laboratory internships to a blended learning format, were accompanied by an evaluation based on the design-based research approach starting in the 2022 summer semester. This approach combines the development and evaluation of innovative teaching/learning approaches and is carried out in several iteration cycles, as shown in Figure 10 [6].



Figure 10: Iteration steps of the design-based research approach

The primary objective of the evaluation was to determine, from the students' perspective, the basic acceptance of the new teaching/learning concept, the time spent by the students, and the learning success achieved through the internships in order to gain insights for the further development of the teaching/learning concepts. The survey was conducted using a questionnaire containing closed questions and free text fields, which was created using the limesurvey program [8]. The survey was usually conducted at the end of each internship cycle and was therefore both summative and formative in nature [4].

Evaluation of the DMS internship (fall semester 2022)

The first run of the blended learning internship trial on the topic of strain measurement (DM) in the summer semester 2022 served as the initial design for the design-based research approach and focused the evaluation on the support services offered. At that time, this included digital consultation (interim discussion), checking the protocols submitted after the interim discussion, and a debriefing.

The results of the evaluation showed an urgent need to revise the supervision concept. Only 53% of students agreed that their questions had been answered during the consultation. For their part, the supervisors stated that the concept of the interim meeting at that time required them to respond spontaneously and adequately to unpredictable questions [4].

Furthermore, it became apparent that the planned debriefing did not succeed as intended. The necessary review of the protocols could not be carried out in the short time frame between submission and debriefing, which meant that the basis for individual feedback was lost. In addition, there was little demand for this supervision service among students.

Another point of criticism that emerged from 40% of all free comments was that students felt the internship required too much time. Students reported needing an average of 18 hours for the DM experiment, which was significantly more than the 11 hours specified in the module description.

This high time expenditure was closely related to technical and structural problems. 52% of the students reported having had major difficulties in completing the internship tasks. Among other things, this was due to the difficulty of reproducing the results because of an unstable measurement system, which led to multiple repetitions of entire test series. An error in the Arduino program provided caused deviations between measurement data and theoretical values, which required a lot of time for troubleshooting. With regard to the exam performance, the analog form of the protocol was rejected by the students. Despite the difficulties, the group work was evaluated positively. 85% of the students stated that they found it easy to contribute to the group work, and 77% agreed that the group work had enabled them to engage intensively with the content.

Redesign and its evaluation (WiSem 2022/23)

The critical results of the initial design led to targeted adjustments in the next iteration. In order to improve supervision, logbooks (based on the concept of reading logs [6]) were introduced as a central element for accompanying and structuring the self-study phase. Students were asked to note their questions in the logbook and upload them before the consultation appointment. This enabled the supervisors to prepare specifically and collaboratively create a catalog of questions and answers. The aim was to relieve the burden on those responsible and create a uniform quality standard. The consultation was designed to be student-centered by using the questions actually asked by students in their logbooks as the basis for the face-to-face session. The debriefing was completely omitted due to low demand and to reduce the workload of the supervisors.

To reduce the criticized time expenditure, the task of "investigating interference" was shortened from three to only two interference factors. In addition, students were allowed to freely choose the bridge circuit, eliminating the time-consuming comparison between quarter and full measurement bridges. To support time management, the "semester overview" was newly introduced to highlight important

dates and recommended tasks (to-dos) for the respective week.

This has become a permanent feature of the lecture (Fig. 11).

November		Dezember	
1Sa		1Mo	Beginn Thementage DM 49
2So	Abgabe Logbücher VPF	2Di	
3Mo	Beginn Thementage VPF 45	3Mi	
4Di	Vorlesung 4	4Do	
5Mi		5Fr	
6Do		6Sa	
7Sa		7So	
8Sa		8Mo	50
9So		9Di	Vorlesung 8
10Mo	46	10Mi	
11Di	Vorlesung 5	11Do	
12Mi		12Fr	
13Do		13Sa	
14Fr		14So	
15Sa		15Mo	51
16So		16Di	Vorlesung 9
17Mo	47	17Mi	
18Di	Vorlesung 6	18Do	
19Mi	Freitag	19Fr	
20Do		20Sa	
21Fr		21So	Abgabe Protokolle DM
22Sa		22Mo	vorlesungsfreie Zeit 52
23So	Abgabe Protokolle VPF	23Di	
24Mo	48	24Mi	
25Di	Vorlesung 7	25Do	
26Mi		26Fr	
27Do		27Sa	
28Fr		28So	
29Sa		29Mo	
30So	Abgabe Logbücher DM	30Di	

To-do für die Woche:
 - Praktikum VPF fertigstellen
 - Protokoll VPF hochladen

Figure 11: Semester schedule with the tasks to be completed each week.

The adjustments to the support concept showed a significant improvement. Student agreement with the statement "My questions were answered during the consultation" rose from 53% to 78%. This trend was also reflected in the free-text comments, with a significant decrease in criticism that questions were not answered during the consultation. The use of logbooks was particularly successful in improving supervision and the design of the consultation [4].

Although supervision was improved, the high workload (21.6 hours on average) remained the biggest point of criticism. Other learning obstacles identified were: high workload (36% of responses), implementation of the experiment (23% of responses), effort/handling of Excel (11% of responses), as many students are inexperienced in using the program and feel uncertain when errors or deviating results occur. Analysis of these challenges led to the realization that the blended learning format places new demands on students. It requires more planning and organization of their own work processes as well as coordination of partner work compared to conventional laboratory internships with fixed time slots. In addition to the pure acquisition of knowledge, a major challenge now lies in the acquisition and application of so-called 21st century skills [9] such as independence, teamwork, initiative, and

creativity in problem solving, competence in dealing with media and technologies, and communication skills.

Evaluation Academic Year 2023/24

There are still six internships, three per semester. In the winter semester, students work on the topics of experimental design and error calculation (VPF), strain measurement (DM), and measurement chain (MK), and in the summer semester, they work on measurement dynamics (MD), programmable logic controllers (PLC), and control loops (RK). The evaluation in the following chapters refers only to the internships in the winter semester, i.e., VPF, DMS, and MK.

Many positive assessments were given, but weaknesses that need to be addressed also became apparent. Overall, the excessive amount of time required and the complexity and difficulty of the experiments were criticized. The unstable circuit was criticized, especially in the DM experiment.

Recommendations for action regarding the measurement chain practical, in particular regarding the wording in the logbook and the protocol, were drawn up and implemented.

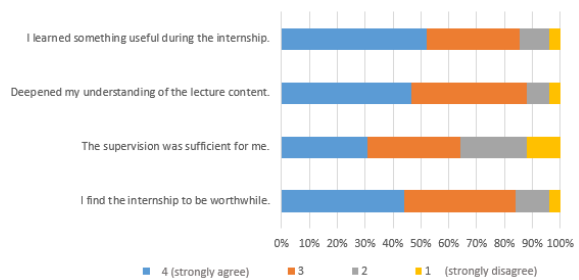


Figure 12: Student assessments of the DM 2023/24 internship

Over 70% of participants found the internship useful and learned something useful (Fig. 12). The consultation was criticized mainly in the free comments, as the students felt that their questions were not answered sufficiently. The consultation was abolished the following year and replaced by theme days (see Chapter 2, Phase 3). Students appreciate the wide range of options available (consultation, exercises, videos, instructions, etc.) and benefit from this variety [3].

Evaluation of theme days (academic year 2024/25)

The results of the most recent evaluation, from the 2024/25 academic year, show that the theme days were very well received by students as a new element of supervision within the framework of internships and that they enjoyed them (Fig. 13).

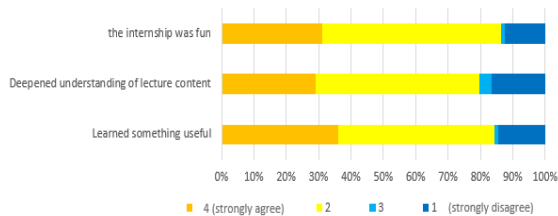


Figure 13: Student assessments of the VPF theme day

Nevertheless, some points should be addressed for revision. While the evaluation of the protocol and logbook improved compared to the previous year, the evaluation of the protocol and logbook decreased from the first to the third internship. The free comments made it clear that the tasks should be formulated more precisely.

The students were still unable to make a sufficient connection to professional practice.

The time required increased significantly from the first internship (mean = 6.4 hours) to the second internship (mean = 9.8 hours) to the third internship (mean = 17 hours). The total time required for the module is 33.2 hours.

The students also rated the achievement of the learning objectives as decreasing from the first to the third internship.

About 40% of the students used the introductory videos. The Arduino guide was used extensively, especially during the second internship (over 80%). Nevertheless, the students would like to see a better introduction to using the Arduino. The use of the Excel data streamer rose from about 25% during the first internship to over 60% in the second and third internships.

The perception of enjoyment and the deepening of lecture content also decreased from theme day one to theme day three.

The protocol continued to receive some negative criticism in the open comments. Students

complained that the internship guidelines needed to be much more precise.

Another positive observation was that while over 50% of participants would have liked additional support in the 2023/24 academic year, this figure fell to less than 20% in the 2024/25 academic year.

Compared to the previous year, the introductory videos were not viewed as much.

By changing the tasks for the internship, an improved introduction to Arduino was already achieved in the 2025/26 winter semester, and it was noticeable in the ongoing internships that the students were able to deal much better with questions that required the use of Arduino.

4. Outlook

Dissemination in electrical engineering

One goal of the overall development of a new and, according to the evaluation, successful teaching/learning concept for modern science/technology internships is the dissemination of the blended learning format in the form of a combination of Praktika@home and theme days to related engineering disciplines. Currently, new Arduino experiments specializing in electrical engineering have been developed in collaboration with student assistants in order to establish a modified practical course in electrical engineering.

Although the new methods obviously pursue better learning outcomes and modern technologies, the actual introduction of the blended learning format in electrical engineering requires extensive restructuring of the current practical courses and the associated training of lecturers and professors.

Digital twin

Based on Prof. Lasch's "DigitalHerrenhut" project [10], a physical Arduino learning space is currently being digitally mapped by creating a digital twin using a 360° camera. This virtual image enables browser-based, navigable exploration of the learning space and the Arduino experiments (similar to Google Street View) from home (Fig. 14). Inside the room, the

experiments from the suitcase lab are visualized and presented in multimedia format.

Students can view each experiment individually (Fig. 15) and access related documents (protocol, logbook, detailed PDF descriptions) as well as YouTube video tutorials [V1-V4]. A key technical challenge is the secure technical solution for authentication, as is currently the case with the materials on the Opal teaching/learning platform. The optimal and secure technical integration is currently being developed. The current status of the twin can be viewed online [11].

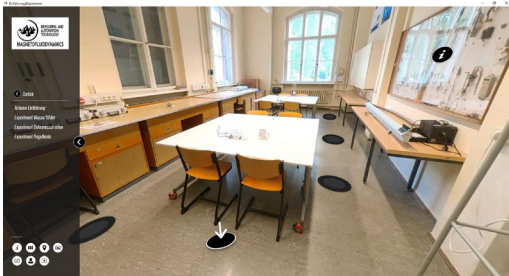


Figure 14: Screenshot: digital twin MAT internship. The 'walkthrough' and exploration is done using points on the floor. Navigation bar on the left-hand side.

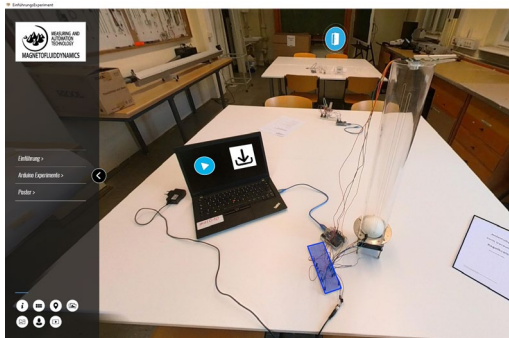


Figure 15: Screenshot: Control loop experiment – options for downloading materials (PDF, Excel), viewing photo and video details of the experimental setup, and YouTube video

Evaluation remains an integral part of the MAT module – especially for the practical, but also for the lecture and exercise. This allows elements to be improved and new elements to be reviewed in order to maximize learning success for students.

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Youtube-Videos:

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- [V2] Versuch „SPS“: <https://youtu.be/59xzLzSkIWw>
- [V3] Versuch „Messdynamik“: <https://youtu.be/mv4U2nx25Q>
- [V4] Versuch „Versuchsplanung und Fehlerrechnung“: <https://youtu.be/GzEDpFrs7tU>